EVAPOTRANSPIRATION AND LEACHATE QUALITY OF WARM-SEASON TURF AND NATIVE GRASSES UNDER DIFFERENT TEXAS LANDSCAPE CLIMATES

A Dissertation

by

TIMOTHY RICHARD PANNKUK

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2009

Major Subject: Agronomy

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Approved by:

Chair of Committee,	Richard White
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	David Chalmers
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ABSTRACT

Evapotranspiration and Leachate Quality of Warm-season Turf and Native Grasses under Different Texas Landscape Climates. (August 2009)

Timothy Richard Pannkuk, B.S.; M.S., Texas A&M University

Chair of Advisory Committee: Dr. Richard H. White

Urban landscapes require irrigation during periods of insufficient rainfall. Significant water use savings may be achieved if landscape irrigation is based on reference evapotranspiration (RET). The objectives of this study were to determine 1.) landscape crop coefficients (K_L) for landscapes comprised of different vegetation types, 2.) if regional climatic differences affect K_L, and 3.) examine differences in leachate nutrient concentrations from the plant treatments. The K_L was determined from the ratio of actual evapotranspiration and a modified Penman equation reference. Irrigation quantity was based on 100% replacement of RET. The K_L were determined for St. Augustinegrass [*Stenotaphrum secundatum* (Walt.) Kutze.] alone, Red Oak [*Quercus shumardii* Buckl.] alone, St. Augustinegrass plus Red Oak, native grasses [*Muhlenbergia capillaries* (Lam.) Trin. and *Schizachyrium scoparium* (Michx.) Nash], and native grasses plus Red Oak in College Station (CS) and San Antonio (SA) Texas, on a Rader fine sandy loam (mixed, semiactive, thermic Aquic Paleustalfs). Soil was systematically placed into lysimeters containing a drainage system and soil moisture probes. Lysimeters (1136 L) were placed in-ground in a randomized complete block

design with three blocks. Soil moisture measurements were made at 0 to 20, 20 to 40, and 40 to 60 cm depths. The K_L was determined after a rainfall or irrigation event for periods of two to five days. Leachate was analyzed for dissolved organic carbon (DOC), dissolved organic nitrogen (DON), ammonium, nitrate-N, orthophosphate-P, and alkalinity.

During the growing seasons of 2007 and 2008, K_L in San Antonio increased from early-, to mid-, to late-season while in CS the K_L decreased from early-, to mid-, to late-season. Treatments with nativegrasses in SA had K_L's as large as 0.91 in late-season. In CS, soil sodium accumulation caused a decreasing seasonal K_L.

Mean DOC concentration was not different between sites except for tree only treatment which was larger in SA. For mean DON concentrations between sites, only the St. Augustinegrass treatment was larger in CS than in SA. Orthophosphate-P concentrations were larger at SA under the tree alone, nativegrass, and St Augustine plus tree treatments than in CS. Ammonium concentration was similar by site for vegetative treatments.

DEDICATION

This dissertation is dedicated to my family – Amanda my wife, Alyssa and Benhardt my children, and the Lord my God. You have waited patiently and lovingly for me to complete the process. For all of this, I am grateful to you.

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. White, and my committee members, Dr. Aitkenhead-Peterson, Dr. Chalmers, Dr. Wingenbach, for their guidance and support throughout the course of this research.

Thanks also go to Dr. Kurt Steinke, Mr. Jim Thomas, and Ms. Nina Stanley for their assistance and guidance during my time as a Ph.D. student at Texas A&M University. I also want to extend my gratitude to the Turfgrass Producers of Texas, Texas Nursery and Landscape Association – Education and Research Foundation, Texas Water Resources Institute, Rio Grande Basin Initiative, Texas Turfgrass Association, Soil And Crop Sciences Department Texas A&M University, and the City of San Antonio, TX – San Antonio Water System.

NOMENCLATURE

CS	College Station, TX
DOC	Dissolved organic carbon
DON	Dissolved organic nitrogen
ET	Evapotranspiration
K_L	Landscape coefficient
RET	Reference evapotranspiration
SA	San Antonio, TX

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CHAPTER I

INTRODUCTION: A REVIEW OF THE LITERATURE

BACKGROUND

Water: A Natural Resource

Water is one of our most precious natural resources. Freshwater accounts for only three percent of water on earth, and of that 69% is tied up in ice (U.S.G.S., 2006). Texas is one of the top water consuming states in the United States (Wagner & Kreuter, 2004). California, Florida, and Idaho are other top water users in terms of total withdrawals (U.S.G.S., 2000). Currently, agricultural irrigation accounts for 60% of the water consumption in Texas (Texas Water Development Board, 2003). However, that share is expected to decline due to fewer irrigated acres and practice of better water conservation techniques on farms (Texas Environmental Profiles, 2005).

In Texas, municipal water use is expected to increase from 24% of total water use in 2003 (21 million people) to 35% of the total use by the year 2050 (41 million people) (Wagner and Kreuter, 2004). Beyond human consumption, water has a variety of uses by the municipal user including: irrigating the outdoor built environment, cleaning, and recreation.

Water: For Irrigation

Outdoor irrigation is a highly visible practice which is the target of many conservation efforts (Barta, 2004; DeSena, 1998; Texas Smartscape, 2006). According

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This dissertation follows the style of *Crop Science*.

to the U.S. Geologic Survey, about 26 billion gallons of water are consumed each day in the nation by humans. Approximately 7.8 billion gallons (30%) of this is used outdoors (U.S.G.S., 1998). Some estimates of outdoor water use are nearly 50 to 80% of the total residential use (Kjelgren, 2000; Tinker and Woods, 2000; Vickers, 2001). Over half of this outdoor water use is for seasonal landscape (turfgrass and woody plant) irrigation (U.S.E.P.A., 2009).

Outdoor water use for landscape irrigation varies seasonally and geographically (Kjelgren, 2000; White et al., 2004). A study of residential water use in twelve U.S. and two Canadian cities (12,000 homes) found outdoor consumption was higher in warmer climates (67%) versus cooler climates (58%) (Mayer et al., 1999). This is likely due to higher evapotranspiration rates in the warmer climates. The mean annual water use among 12,075 homes in the study was 146,100 gallons (+/- 103,500 gallons) per household per year. Residential lot square footage has also been found to have a positive correlation with water use (Mayer et al, 1999; Tinker and Woods, 2000; Tinker et al., 2005). Larger lot size is associated with increased outdoor water use. Additionally, homes with swimming pools may use twice as much water outdoors compared to those not having a pool (Mayer et al, 1999). Tinker and Woods (2000) found a positive correlation between indoor water use and outdoor water use after determining a base indoor water usage of 7,530 gallons per month per household in College Station, Texas. Users with high indoor water use, tended to have high outdoor water use. The authors provided no substantive explanation for this. Tinker and Woods (2000) further determined that temperature dependant outdoor water usage was affected

by the presence of an automatic sprinkler system. A sprinkler system, when compared to manual watering, decreased the amount of water used outdoors. It was suggested that home owners with manual systems were likely to irrigate in one location longer than required. Mayer et al. (1999) determined homes with in-ground sprinkler systems use 35% more water than those homes that do not have an in-ground sprinkler system.

Water: Managing the Resource

U.S. water supply companies will experience peak water demands on a summer day that are 1.5 to 3 times higher than a winter day (Vickers, 2001). Municipal water suppliers have a limited capacity to meet peak demands in the summer season. When potential peak summer days are calculated, municipal water suppliers must design water treatment facilities that are 2 to 3 times larger than the daily demand. This excess water treatment capacity is required only a few days each year creating a significant cost in the design, implementation, and maintenance of these water treatment facilities. Use of water conserving techniques in the landscape will be less expensive to implement than building larger treatment facilities or constructing more water wells (Vickers, 2001). Approximately $1 billion is spent each year in Texas alone to update water and wastewater facilities in order to keep up with the rising demand for water supply and wastewater treatment (Tinker and Woods, 2000). Approximately $65 billion will be needed by 2050 for proposed new water treatment, supply, and drainage infrastructure (Texas Environmental Profiles, 2005). This considerable cost is due to expected increases in Texas population. Water conserving alternatives by users would be one way to curb some of these costs. With the increasing demand for water resources in Texas,

the Governor's Task Force on Conservation identified water supply limitations as one of two of the most important issues in Texas. This concern is in part due to the Texas Water Development Boards (1995) finding that conventional fresh water supplies in Texas were about 75 to 80% developed. The population of Texas, however, is anticipated to double by 2050 (TWDB, 2003).

Reducing peak water demand by conservation education, odd-even watering days, and increasing water cost rates have been implemented by municipal water suppliers, government agencies, and citizen groups. Increasing the cost of residential water consumption encouraged conservation in some municipalities (Desena, 1998; Vickers, 2001). For example, Irvine Ranch Water District (Irvine, CA) implemented an increasing block structure to water pricing that reduced outdoor watering among its customers by 50%. The Albuquerque N.M. Water System started a comprehensive conservation education program in 1995 to reduce per capita water use. By 2004, water use had been reduced by 34% compared to 1995 figures (City of Albuquerque, 2006). This involved watering days determined by odd or even street address, restricting time-of-day for watering, and the use of xeric plants. Time-of-day violations include fines ranging from $20 for first offense up to $1000 for offenses thereafter (City of Albuquerque, 2006). Water conservation officers and a Water Waste Hotline were used to enforce watering restrictions. The process of landscape design and planning has been heralded for nearly three decades as a beginning point for water-efficient landscapes (Welsh et al., 2000; Xeriscape Colorado, 2005). Evidence shows however that

homeowner irrigation practices have not changed substantially with landscape designs of water efficient plantings (Peterson et al., 1999).

Water: Reference Evapotranspiration

Geographical differences in water use across the nation are likely due to differences in evapotranspiration (ET). ET is the water loss through evaporation from soil and plant surfaces, and through plant transpiration.

Reference evapotranspiration (RET) is a water loss rate based on environmental demands. The concept was first introduced in the late 1940's (Penman, 1948) and is of great importance to the agricultural, hydrologic, and meteorological sciences. The Penman-Monteith form (F.A.O., 1998) of the combination equation is:

$$\lambda ET = \frac{\Delta(R_n - G) + \rho_a c_p (e_s - e_a)/ r_a}{\Delta + \gamma(1 + r_s/ r_a)}$$

where:

R_n is the net radiation

G is the soil heat flux

$(e_s - e_a)$ represents the vapor pressure deficit of the air

ρ_a is the mean air density at constant pressure

c_p is the specific heat of the air

Δ represents the slope of the saturation vapour pressure temperature relationship

γ is the psychrometric constant

r_s and r_a are the (bulk) surface and aerodynamic resistances.

Landscape irrigation based upon ET is an emerging area of water conservation. White et al. (2004) demonstrated that the potential exists to conserve water in landscape irrigation by using RET. Comparisons were made of actual homeowner water use in College Station, Texas to a prepared "water budget". Evapotranspiration data were used to create this monthly water budget. The water budget indicated possible water savings of 24 to 34 million gallons per year for the city. This savings would have occurred among the 800 households had they irrigated based on RET numbers. Even greater water savings would have been realized had a percentage of RET been used (e.g. 70% rather than 100%) for irrigation.

Evidence also indicates that most turfgrasses and some ornamental plants may be irrigated based on a fraction of the total ET. This fraction of ET is denoted with the coefficient (k). Warm-season turfgrasses growing in the field have reported k values of 0.5 to 0.8 of ET depending on season and geographic location (Brown et al., 2001; Carrow, 1995; Meyer and Gibeault, 1987). Levitt, et al. (1995) reported that live oak and mesquite trees growing in containers have k values of 0.5 and 1.0 of ET respectively.

The possibilities of determining a crop coefficient (k) for an entire landscape of mixed plant species serves as another means of reducing outdoor water use and may contribute to municipal water conservation. Costello, et al. (1992) attempted to apply a crop coefficient to a heterogeneous landscape application. This method used several variables (species, planting density, microclimate), none of which were calculated from field measurements. The variables were qualitative approximations of the factors in the

landscape. This creates difficulty in comparing this particular landscape coefficient model to a crop coefficient value. There is a need for more information that will satisfy the requirements of heterogeneous landscape irrigation practices - if it is to be done in a manner consistent with ET principles.

Transpiration: Soil Influences

Plant transpiration is the loss of vaporous water primarily through the stomates of leaves and stems (Taiz and Zeiger, 2002). Approximately 95% of the water taken up by roots and translocated via the xylem is lost through the stomates to the atmosphere. The balance between water uptake and vaporous loss by plants is vital to plant survival. The rate of transpiration can be affected by several complex factors including soil.

If one considers the soil of plants, it is typically mineral matter. This mineral matter is a combination of sand, silt, and clay sized particles, and a small amount of organic matter in various states of decay. The medium can also be described as having multiple functions for the plant such as water holding, nutrient holding, and stability. Water holding ability of the soil is created by either the voids between the particles occupied by water, or as thin films of water surrounding the particles. The effective amount of water held by the soil is determined primarily by the percentages of sand, silt, and clay. The percentage of sand, silt, and clay determine soil texture.

As water moves into the soil, it occupies the voids and surrounds the particles. Plants will absorb this water causing soil drying if the water absorbed is not replenished by rainfall or irrigation. Soil with a high sand content (low porosity) has a lower water holding ability than a soil with high clay content (high porosity). Therefore, a plant

growing in a clayey soil will have more plant available water for transpiration than a plant growing in a sandy soil. Water held at a potential of 0 to -1,500 kPa is generally considered available for plant uptake (Gardiner and Miller, 2008).

The soil hydraulic conductivity is a measure of ease in which water moves through the soil (Gardiner and Miller, 2008), and it varies with the soil texture and water content. Sandy soils with greater amounts of macropores between particles have a greater hydraulic conductivity. Clayey soils, dominated by micropores between particles, have a low hydraulic conductivity. As soil drying occurs during water uptake by plants, soil hydraulic conductivity decreases which affects stomatal aperture in the plant canopy (Schulze, 1986). This affect on stomata may reduce transpiration. Hubbard et al. (2001) found transpiration, as measured by stomatal conductance, to vary linearly with soil hydraulic conductivity in Pinus ponderosa seedlings. As hydraulic conductivity declined, transpiration declined (r^2>0.90). Else et al. (2001) reported the effects of soil flooding on transpiration. Within 2 to 6 hours of the flooding treatment, transpiration was slowed when compared to the non-flooded controls. The authors also measured the flooded plants root hydraulic conductivity. The root hydraulic conductivity of the flooded plants was reduced by 47% compared to the control plants. This reduced root hydraulic conductivity in the oxygen-deprived roots promoted visible wilting within 3 hours in the flooded treatment. Extremes in soil moisture content, both saturation and dryness, can affect plant transpiration.

Total soil salt also impacts plant transpiration. Soil salts are the total concentration of minerals composed of cations and anions including sodium, calcium,

potassium, chloride, and carbonates (Miller and Gardiner, 2008). The salts may occur naturally due to the parent material. As soil salt concentrations increase, the soil water available for the plant is increasingly diminished. This is referred to as the osmotic potential of the soil water potential (Taiz and Zeiger, 2002).

Soil salinity affects plants ability to take up water for transpiration and for other metabolic processes (Munn, 2002). Wang and Nii (2000) demonstrated how the herbaceous ornamental *Amaranthus tricolor* L. exposed to high (300 mM) soil NaCl for 7 days exhibited reduced transpiration compared to control plants. At the end of the seventh day, the authors placed the salt treated plants in salinity relief for 7 days. During the salt relief period, transpiration rates gradually returned to those rates of the control plants. In some instances, the soil salinity may bring about elevated levels of a single element (i.e. B and Cl) that can effect plant transpiration. Ben-gal and Shuni (2002) found transpiration in tomato (*Solanum lycopersicum* L.) leaves to be reduced by a combination of elevated Boron levels and soil salinity. The authors grew tomato in various concentrations of boron. Boron, like most other salts, is an essential plant nutrient, but when in excess the salts can modify plant-water relations.

Transpiration: Climatic Influences

Climatic factors influencing plant transpiration include temperature, vapor deficit, wind speed, and solar radiation. These factors vary in their influence on plants both daily and seasonally. The climatic factors are to some degree inter-related in their affect on transpiration.

In non-limiting soil water conditions, transpiration can be affected by air or soil temperatures. Mellander et al. (2004) confirmed the importance of soil temperature in *Pinus sylvestris* L. transpiration. Young trees were manipulated by covering the soil with snow for various times thereby simulating different rates of soil warming during the spring season. In their study, soil temperatures below 8° C were a factor in reducing transpiration through reduced stomatal conductance. The effects of soil temperatures on transpiration did vary in part due to air temperatures and day-length. Kellomaki and Wang (2000) studied the effects of increased air temperature and increased CO_2 concentration on the transpiration of *Pinus sylvestris* L.. Thirty year-old trees were enclosed in structures to modify conditions of temperature and CO_2. The treatments of increased temperature (2° C greater than the control) and increased temperature plus increased CO_2 had significantly higher transpiration, as measured through sap flow, than the control trees.

Vapor deficit usually reaches a minimum at a time when temperature is at a minimum. It tends to be greater in the day than in the night. As with temperature, vapor deficit can have an effect on transpiration. Vapor deficit can be measured and used as an estimate of the driving force of transpiration (Campbell and Morgan, 1998). The difference in water vapor concentration between the stomatal cavity and the air is a significant force in transpiration (Taiz and Zeiger, 2002). Nobel (1999) used a derivation of Fick's first law of diffusion to calculate water potential gradients in the soil-plant-water continuum. Assuming a temperature of 25° C and a mesophytic plant, water vapor potential inside a stomatal pore can be -7.04 MPa, and just outside the

stomatal pore it can be -103.7 Mpa. This gradient causes water to move from inside the stomatal pore to the atmosphere. Again, this transpirational pathway is also temperature dependant.

Exposure of *Cucumis sativus* L. to high atmospheric vapor deficit and increased illumination caused increasing transpiration (Shibuya et al.,2006). *Cucumis* stem cuttings were taken after the treatment was imposed. The cuttings were then rooted in an area void of the treatments. Subsequent growth and transpiration of plants previously exposed to low humidity and illumination was greater than those cuttings that did not receive a low humidity treatment.

Typically as solar radiation increases, stomata open and transpiration and photosynthetic rates increase. As the photosynthetic rate increases, the plant requirement for CO_2 increases. The open stomata create a low resistance pathway for water vapor to move out into the atmosphere (Taiz and Zeiger, 2002). The diurnal pattern of solar radiation affecting transpiration is usually stated in textbooks as stomata open in the day, and closed at night when photosynthesis stops. However, trees and shrubs may transpire during the night time hours if soil water deficit is near zero (Dawson et al., 2007). During conditions of high night time evaporative demand or low soil water availability, these same plant species had significantly reduced transpiration. Dawson et al. (2007) measured this response in eleven tree species and seven shrub species taken from several ecosystems.

Transpiration: Topographical Influences

The hillslope scale topography of land may also impact the transpiration of plants growing on the hillside. Patterns of variation in soil depth on the hillside may create patterns of variation in available plant water in the soil (Tromp-van Meerveld and McDonnell, 2006). In this study, soil moisture and stem sap flow were measured in trees across the hillside. Stored soil moisture at the end of the wet season caused measurable differences in transpiration rates between upslope and midslope trees at the end of summer. The authors state that this spatial variation in total water availability is partially responsible for the species distribution pattern on the hillslope.

Differences in transpiration rates at the topographic level have been detected in large areas (800+ hectares) with satellite imagery using a water deficit index (Holifield Collins et al., 2003). This sophisticated system estimates transpiration by using meteorological data and a relation between reflectance and temperature.

The aspect of a hillslope may impact plant transpiration as well (Miller and Gardiner, 2008). Those slopes oriented toward a southerly direction will receive a higher incident angle of solar radiation per unit area than the northerly slopes. The higher energy input into the south slope will raise soil and soil water temperatures faster during the spring and summer. This also results in the south slope with a higher rate of water evaporation. During periods of intermittent rainfall, less water may be available for transpiration compared to north-facing slopes.

Transpiration: Tissue Age Influences

Plant tissue age has shown to impact plant transpiration. Young, fully expanded leaves typically have high transpiration rates as they manufacture sugars and metabolites for various growing points. Older leaves will transpire at a lower rate due to reduced photosynthetic activity in *Zea mays* (Xu et al., 2008) and six tropical trees (Sobrado, 1994). In some species, the development of thick waxy surfaces or hairs (trichomes) aids plant water retention and reduces wind velocity across the leaf. Buffalograss (*Buchloe dactyloides* [Nutt.] Engelm.) is a very drought tolerant grass of the central plains states with hairs on adaxial and abaxial leaf surfaces (Turgeon, 2005). The hairs originating from the leaf surfaces reduce the wind velocity on leaf surfaces. The reduced surface wind velocity results in reduce boundary layer disturbance. This will effectively reduce the transpiration rate (Beard, 1973). As leaves approach senescence, the rate of transpiration is very low as photosynthesis ceases (Adedipe et al., 1971).

Transpiration: Plant Form Influences

Tree and grass species may differ in their rates of transpiration. The tree specie with its leaves raised above the ground surface is experiencing higher wind speeds than the leaves of the grass. Wind speed is near zero at the surface but increases rapidly with height above the surface (Maki, 1975). The amount of air turbulence increases with height above the surface (Gifford, 1968). The increased wind speed causes increased boundary layer conductance for the canopy (Campbell and Norman, 1998). For this reason, many trees have higher transpiration rates than the nearby grasses.

Transpiration: Photosynthetic Pathway Influences

Plants are grouped into C_3 and C_4 types based on their leaf anatomies and enzymes used to carry out photosynthesis. These differences are important with respect to their optimal growing conditions and N and water-use efficiency. The C_3 species have temperature optima of 15 to 30 C° whereas C_4 species have temperature optima of 25 to 40 C°. In the C_4 photosynthetic pathway, PEP carboxylase has a high affinity to CO_2 (Hatch and Slack, 1966). This allows the C_4 plants to reduce the stomatal aperture and conserve water while fixing CO_2 at rates equal to or greater than C_3 plants during exposure to high temperatures. This feature of photosynthesis might be a reason for C_4 plant domination in drier, hotter climates. Although most of the North American grassland biome is dominated by C_4 species, C_3 species become more important with increasing latitude and elevation because of the cooler climate (Kephart et al. 1995).

CHAPTER II

LANDSCAPE COEFFICIENTS FOR SINGLE- AND MIXED-SPECIES LANDSCAPES IN SOUTHERN TEXAS

INTRODUCTION

Water is one of our most valuable natural resources and water conservation continues as a major national priority (Vickers, 2001; TWDB, 2007). Due to population growth, current potable water supplies will be insufficient by the year 2050 in Texas (TWDB, 2003). Currently, 7.8 billion gallons, or about 30% of all potable water is used outdoors (USGS, 2006) primarily for landscape irrigation (Kjelgren et al., 2000; Vickers, 2001; White et al., 2004).

Landscape plants provide an aesthetic appeal to urban landscapes, prevent erosion of the soil that impairs surface water supplies, and improve recharge of groundwater (Beard and Green, 1994). Irrigated areas within the built landscape can also increase property values (Vickers, 2001). Yet, consumer lack of understanding as to landscape water management practices will routinely contribute to excess water use. A study of 800 home consumers in College Station, Texas estimated that an excess of 24 to 34 million gallons of water were used annually for landscape irrigation during 2001 through 2003 (White et al., 2004). Landscape design and planning has been heralded for decades as a step towards water conservation (Welsh, 2000; Xeriscape Colorado, 2005). Yet, water consumer irrigation practices did not change with landscapes designed for water conservation (Peterson et al., 1999).

Evapotranspiration (ET) is the amount of water lost through evaporation from the soil and plant surface, and through plant transpiration. Reference evapotranspiration water loss rate is based on environmental demands for a short green perennial crop completely covering the ground. Landscape irrigation based upon ET is an emerging area of water conservation since irrigation based on ET links plant water use to irrigation water replacement rates and schedules. There is evidence that reference ET weather station data can be a determinant in irrigating landscape plants (Shaw and Pittenger, 2004; White et al., 2004). Yet, there is a lack of information on the fundamental seasonal relationships between ET and actual evapotranspiration of turfgrass and native grass species under different landscape climates. An understanding of this relationship is critical to providing recommendations for landscape irrigation based on reference ET.

The objective of this study was to a) Compare actual ET to reference ET by climate and treatment, b) determine if seasonal and regional differences in landscape irrigation coefficients occur.

MATERIALS AND METHODS

Site Description

The experiment was conducted at two sites; Texas A&M University Turfgrass Field Laboratory College Station, Texas and at a site adjacent to the San Antonio Water System Leon Creek Waste Water Treatment Facility in San Antonio, Texas. These two sites will be referred to as the College Station region and the San Antonio region. College Station on average has greater rainfall and humidity than San Antonio (Table 1).

Table 1. Average rainfall, average relative humidity (RH), average maximum temperature (TMax), average mean temperature (TMean), average minimum temperature (TMin), and average cumulative reference evapotranspiration (RET) for College Station and San Antonio, Texas.

	College Station	San Antonio
Rainfall (mm)	1000	764
RH (%)	47.83	42.85
TMax (ºC)	25.8	26.6
TMean (ºC)	19.9	20.5
TMin (ºC)	14.2	14.4
RET (mm)	1430	1522

Lysimeter Construction and Sensing

Individual waterproof lysimeter containers were 1,136 L oval stock tanks (R.G. Applegate Steel Co., Saratoga, Indiana) 2.43 m long x 1.02 m wide x 0.68 m deep. Tanks bottoms were constructed from 1.0 mm galvanized steel and sides were made from 0.85 mm galvanized steel. Tanks were placed in-ground on a smooth level surface such that the tank tops were 5 cm beneath the surface grade. The bottom of the tank was filled with 1 cm diameter gravel to 5.1 cm depth. A PVC drainage pipe system was embedded in this gravel layer to allow vacuum drainage. The drainage pipe consisted of three 1.83 m long pieces of 1.27 cm diameter pipe manifold together and joined at one end with a 0.76 m tall standpipe (Figure 1). The end of each lateral was permanently capped. Three mm diameter holes were drilled in the bottom of each lateral line at 10 cm spacing to allow water to enter the pipes. The space between the individual lysimeters was 30.5 cm.

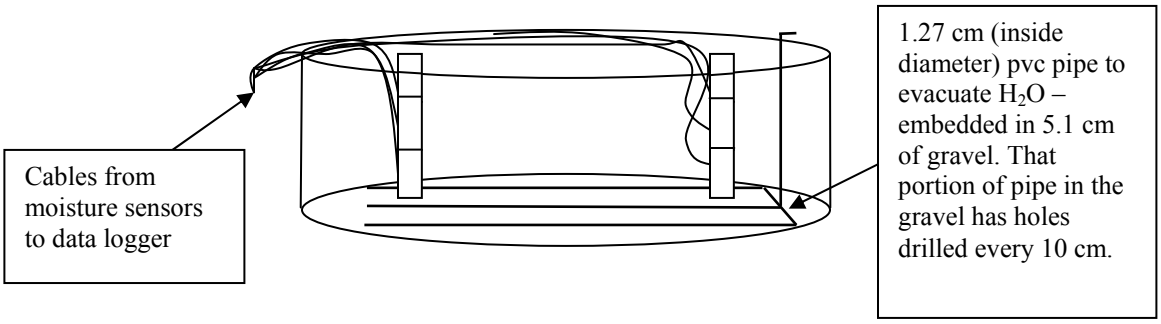

Figure 1: Schematic drawing of the lysimeter design.

After the installation of the drain lines and gravel layer, soil was added in lifts. The soil was from the A horizon of the Rader fine sandy loam soil series (fine-loamy, mixed, semiactive, thermic Aquic Paleustalfs). All soil was passed through a 1.27 cm diameter screen to remove stones, roots, and other undesirable materials prior to placement in the lysimeter. Approximately 15 to 20 cm of loose soil was added and manually compacted with a hand tamper to a finished depth of 10 cm. The surface of each lift was lightly scarified with a garden rake prior to adding the next lift of soil. When the soil surface reached 10 to 15 cm below the top of the lysimeters, a 15 cm wide strip of 0.1 mm plastic was taped to the inside of the lysimeter wall using duct tape. This plastic sheet was allowed to extend horizontally toward the center of the lysimeter on top of the soil. The plastic sheet provided a mechanical barrier to reduce the potential for side wall flow and helped force downward moving water away from the side walls of the lysimeters so that it would flow through the bulk soil (Brown et al., 1985). Continuation of soil lifts to the lysimeters brought them to filled capacity. Lysimeters

for the San Antonio location were built in College Station, transported to San Antonio, and installed in-ground.

Six soil moisture sensors (ECH2O Probes, Model EC-20, Decagon Devices, Pullman, WA) were placed in two locations in each lysimeter (three sensors per location). Sensors monitored volumetric water content at 0 to 20, 20 to 40, and 40 to 60 cm depths (soil surface down to the gravel layer). Cables from the sensors were routed along the inside edge of the lysimeters to one end and subsequently taped to the inside of the lysimeter (Figure 1). From the lysimeters, the cables were enclosed in a 10 cm diameter perforated corrugated drainage pipe and routed to a nearby data collection station. Volumetric soil moisture content was collected using a data logger (model 10X, Campbell Scientific Inc., Logan, UT) coupled with model AM 16/32 multiplexers. Measurements were taken every 15 minutes and averaged for every 30 minutes. At the College Station location, a hand held PDA (Palm, model 500m) and appropriate software (P Connect, ver. 2.0, Campbell Scientific Inc.) was used to manually download data from the data loggers. At the San Antonio location, data collection was accomplished using a Com 210 modem and analog telephone line (Com 210, Campbell Scientific, Inc., Logan, UT). This allowed daily transfer of data to a central computer in College Station.

Lysimeters at each location were irrigated with a two zone in-ground automatic system. Irrigation spray heads (Toro 70 Series Bloomington, MN) were installed at 3.65 m triangulated spacing. A water meter was installed in each zone to allow measurement of total applied water.

A weather station was located within 250 m of the lysimeters at College Station and San Antonio. Environmental data included precipitation, radiant energy, wind speed, humidity and temperature. Data from these stations were used to calculate reference evapotranspiration using a modified Penman-Monteith equation (FAO, 1998). Irrigation was adjusted every 2 to 3 wk to replace 100% of calculated reference evapotranspiration minus precipitation. During periods when irrigation water was required, water was applied one or two days per week.

Treatments

Treatments were arranged in a randomized complete block design with three replications. The plant treatments were randomly assigned to the lysimeters within each block. The following plant taxa were used: *Stenotaphrum secundatum* [Walt.] Kuntze. (St. Augustinegrass), *Quercus shumardii* Buckl. (shumard red oak), *Schizachyrium scoparium* [Michx.] Nash (little bluestem), *Muhlenbergia capillaries* [Lam.] Trin. (muhlygrass). Table 2 lists the plant treatment combinations.

Table 2. Plant combination for each treatment.

	Treatment				
	1	2	3	4	5
St. Augustinegrass	x	-	-	x	-
Shumard red oak	-	x	-	x	x
Nativegrasses - little bluestem & muhlygrass	-	-	x	-	x

Plant installation occurred on Dec 19, 2006 and Dec 20, 2006 for the San Antonio and College Station locations, respectively. To avoid disturbing sensors and

sensor cables, container-grown (11.4 L) shumard red oak trees were planted in the center of the lysimeters. Treatments receiving St. Augustinegrass and bermudagrass (All Seasons Turf Grass Inc., Brookshire, Texas) were planted with sod grown on a Katy fine-sandy loam series (fine-loamy, siliceous, thermic Aquic Paleudalf). Nativegrass treatments received nine, field-grown (3 L root ball) individual little bluestem and two, container-grown (5.7 L root ball) individual pink muhlygrass. The nativegrass plus red oak treatment received eight little bluestems and two pink muhlygrasses. Nativegrasses were spaced equidistant across the lysimeter.

Site Management

St. Augustinegrass was maintained at 5 to 7.6 cm cutting height with a frequency of every two to four weeks. Clippings were returned to the plots. The bluestem and muhlygrass (nativegrass treatment) were trimmed to 15 to 18 cm each December. The soil in the St. Augustinegrass alone treatment was sampled (0 to 15 cm depth) for laboratory analysis two to three times each year (Soil, Water, and Forage testing Lab College Station, TX). Based on soil analysis, a balanced fertilizer was added to all treatments during 2007 and 2008. Nitrogen at a rate of 48.8 kg ha^{-1} was applied in three separate events each year. Plant tissue analysis was conducted in July 2008 for only the St. Augustinegrass treatment. This was completed to indicate plant health and potential negative effects of soil salts.

Azoxystrobin (Methyl 2-2-6-(2-cyanophenoxy) pyrimidin-4-yloxy-phenyl-3-methoxyacrylate) fungicide was applied in March 2007 to turfgrass treatments for brown patch (*Rhizoctonia solani*) control. Fipronil (5-amino-1-[2,6-dichloro-4-

(trifluoromethyl)phenyl]-4-[(1R,S)-(trifluoromethyl)sulfinyl]-1H-pyrazole-3-carbonitrile) insecticide was applied according to label recommendation in 2007 and 2008 for red imported fire ant control. All shumard red oak trees received triforine ([N,N-bis-(l formamido-2,2,2- trichloroethyl)-piperazine) fungicide at budbreak in Mar 2008 to prevent symptoms of anthracnose. A 1 m perimeter was treated monthly with glyphosate (2-(phosphonomethylamino) acetic acid) herbicide at both locations. Lysimeters were evacuated every 2 to 4 wk to avoid saturation of the gravel layer.

Landscape Coefficient Determination

Landscape coefficients were determined from changes in volumetric water content during 2 to 5 days of soil drying and from reference ET amounts during the same period. Soil drying periods occurred due to lack of precipitation and during intervals between irrigation. Soil drying periods began at 0001 hr 24 to 48 hr after an irrigation or precipitation event, and continued until 0001 hr before an irrigation or precipitation event ended the drying period. Changes in soil water volume during soil drying periods provided actual evapotranspiration data for each treatment. Actual Evapotranspiration and reference ET data were used to calculate landscape coefficients by:

$$K_L = actual\ ET \div reference\ ET$$

where:

K_L = landscape coefficient

Actual ET = actual evaporation and transpiration water loss

Reference ET = hypothetical evaporation and transpiration water loss

Observations were grouped into early-, mid-, and late-season (Table 3). Early-season was designated as ordinal calendar days 78 to 153 (75 days), mid-season as days 154 to 259 (105 days), and late-season as days 260 to 335 (75 days). This grouping of dates into three seasons corresponds to patterns of seasonal water deficit (Figure 2).

Table 3. Calendar dates used for Landscape Coefficient calculations.

	College Station	San Antonio
	2007	
Early season		
	Mar 21-25, Apr 27-28, May 4-5, June 1-2	Mar 21-25, 28-29, Apr 26-27, May 3-4, 28-29
Mid season		
	Jun 11-12, Jul 9-13, Jul 28-Aug 1, 6-9, Sep 11-16	Jun 13-15, Jul 26-31, Aug 13-15, 27-30, Sep 6-11
Late season		
	Oct 8-11, 17-21, 23-24, Nov 1-4	Oct 9-12, 17-19, 30-Nov 4, Nov 13-16
	2008	
Early season		
	Mar 21-25, Apr 7-11, May 8-9, 18-22, 24-28	Mar 19-21, Apr 1-3, 27-30, May 5-8, 20-23
Mid season		
	Jun 2-5, 9-12, 16-19, 23-26, Jul 21-22, 28-31	Jun 3-6, 10-13, 17-20 24-27, Jul 15-18, 29-Aug 1, 6-9
Late season		
	Sep 23-26, 30-Oct 3, 12-14, 20-23	Sep 16-18, 22-25, Oct 6-9, 20-22

Irrigation Water Analysis

Irrigation water from both sites was submitted for laboratory analysis in July 2008. Results from the analysis are presented in Table 4.

Table 4. Irrigation water pH, electrical conductivity (EC) and plant nutrients, calcium carbonate and sodium content, and sodium adsorption ratio (SAR) for College Station and San Antonio, Texas.

Region	pH	EC	PO_4	K	Ca	Mg	SO_4	$CaCO_3$	Na	SAR
		S m^{-1}	- - -

Stomatal Conductance

A steady state diffusion porometer (Leaf Porometer, Model SC-1, Decagon Devices Pullman, WA) was used to measure leaf stomatal conductance. Every 4 to 6 wk during active growth, conductance was measured in all treatments near solar noon under non-limiting soil moisture conditions. Three undamaged, recently matured leaves (subsamples) were randomly selected from each treatment-block with St. Augustinegrass. The area of the St. Augustinegrass covering the lysimeter was visually divided into three equal areas, and one leaf from each of the three areas was selected for measurement. In treatments with red oak tree, a leaf from the lower, mid, and upper canopy in full sun exposure was used for measurement. The porometer's sensor was placed on the red oak leaf at the first or second lobe behind the apex as to not cover a vein. Those treatments with nativegrasses included two measurements from little bluestem and one measurement from muhlygrass per block. In both nativegrass species, the sensor was placed midway on the leaf blade of a randomly selected leaf. Leaves located in full sun exposure were selected.

Biomass Accumulation

In Nov 2007 and Nov 2008, the above ground accumulation of native and turfgrass leaves and stems both living and in various states of decay were collected for a season-end biomass calculation. In those treatments with St. Augustinegrass and nativegrasses, a 100 cm^2 flat, square grid was randomly placed on the lysimeter. Leaves and stems, of the grasses only, in the three-dimensional volume of the square grid were harvested and placed in a drying oven at 105° C. Dry mass was measured using an

analytical balance 96 hours later. Dry mass was used to calculate kilograms biomass per hectare.

Plant Visual Rating

Plants were rated on visual quality by treatment from Mar 2007 through Aug 2008. The rating system was on a scale of 0 to 9. Zero represented a complete absence of green color, and 9 represented completely green canopy.

Tree Caliper Measurement

Average tree caliper was 2.0 cm during installation (Steinke et al., 2008). Tree caliper was measured again in Nov 2008. The caliper tool was placed on the tree trunk 15 cm above the soil grade. Two measurements were taken at this location on the tree. When the caliper tool was placed on the trunk and the trunk measured, the tool was then rotated horizontally 90º for the second measurement for that tree. The arithmetic average of these two measurements was used for each tree.

Statistical Analysis

Treatment K_L values, biomass accumulation, and stomatal conductance were subjected to Proc GLM in SAS v. 9.1 (SAS Institute, 2003) for a randomized complete block design with a factorial structure that included regions and seasons. Treatment means were separated by Scheffe's mean separation test. Effects were considered statistically significant at $P \leq 0.05$. Statistical hypotheses were as follows:

mean K_Ls were the same by treatment, season, and region;

mean biomass accumulations were the same by treatment and region;

mean stomatal conductances were the same by treatment, season and region.

RESULTS

Landscape Coefficients

The analysis of variance indicated a significant year by region by treatment interaction. Therefore, data were analyzed and presented by year. During eight months in 2007, the mean K_L was greater for nativegrass plus tree than for tree alone (Table 5). The K_L for nativegrass, St. Augustinegrass plus tree, and St. Augustinegrass were similar. The untrimmed native grasses increased in height and girth from spring until the first frost in November, whereas the mowed St. Augustinegrass had a relatively constant plant height and density during this time period. Plant canopy size may have contributed to the differences in K_L between the low growing turfgrass and the upright bunchgrass type growth of the nativegrasses.

Table 5. The K_L for individual and combined plantings by region and season during 2007.

	K_L						
	CS			SA			Combined
	Early	Mid	Late	Early	Mid	Late	Regions
St. Augustine	0.81^{NS}	0.31^{NS}	0.32^{NS}	0.40^{NS}	0.56^{NS}	0.58^{NS}	0.49 ab†
St. Augustine + tree	0.77	0.38	0.28	0.54	0.50	0.60	0.51 ab
Tree	0.20	0.21	0.28	0.36	0.51	0.68	0.37 b
Native	0.59	0.49	0.27	0.50	0.57	0.68	0.52 ab
Native + tree	0.59	0.50	0.47	0.59	0.70	0.91	0.63 a
seasonal mean	0.59	0.38	0.32	0.48	0.57	0.69	
year mean		0.43 B‡			0.57 A		

^{NS} not significant

† Means with the same lower case letter within column are not significantly different under Scheffe's mean separation test at $p \leq 0.05$.

‡ Means with the same upper case letter within row are not significantly different under Scheffe's mean separation test at $p \leq 0.05$.

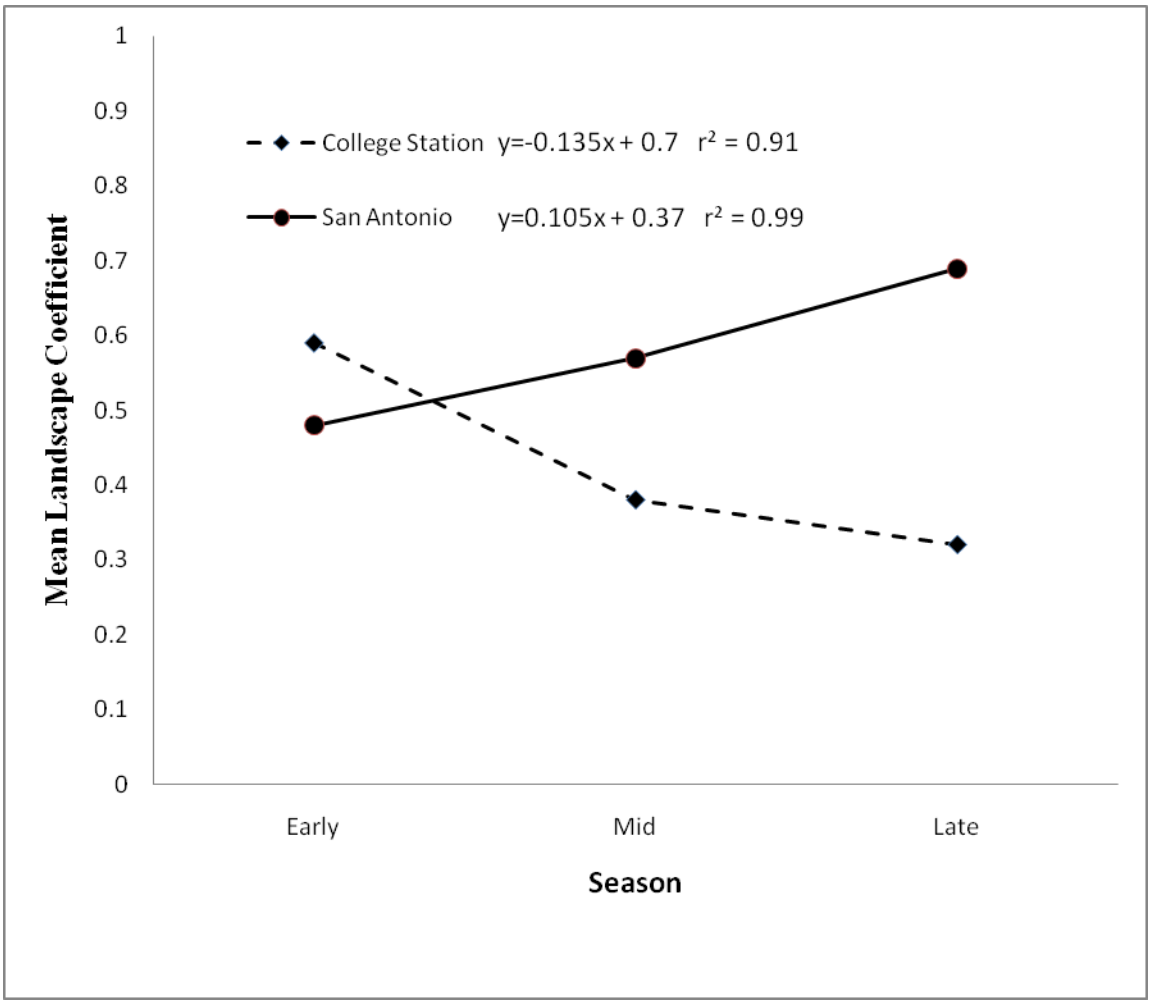

Figure 3. Mean landscape coefficient by region for 2007.

There was a significant region by season interaction effect on K_L in 2007. In the San Antonio region, K_L increased from early-season to late-season. However, K_L generally decreased from early-season to late-season in the College Station region (Figure 3). Cumulative reference evapotranspiration for 2007 was greater in San Antonio than College Station (Figure 4). However, the rate of accumulation was similar for both regions from June through November. This reference ET pattern at the two

sites is evidence that some other environmental factor influenced the differences in K_L between the two regions.

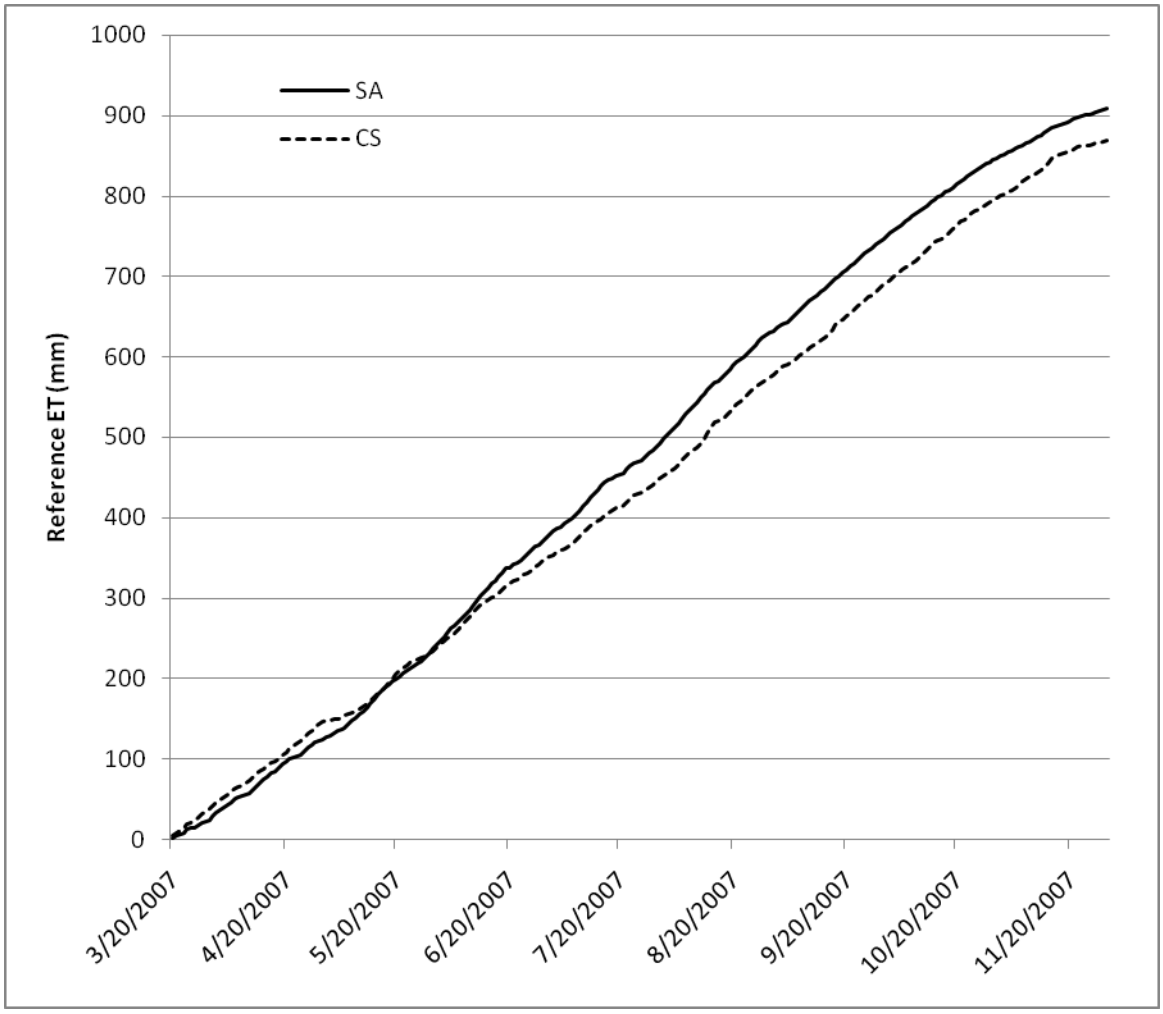

Figure 4. Cumulative reference evapotranspiration by region from March 20, 2007 to Nov 30, 2007.

There was a significant region by season by treatment interaction effect in 2008. Therefore data were analyzed by region within year for 2008. In 2008 in the College

Station region, K_L was significantly impacted by season. Seasonal K_L decreased from early- to mid- to late-season (Table 7). The K_L was similar among plant treatments in College Station for 2008 (Table 7). From Mar 1 to Oct 3, 2008 in College Station, precipitation was 519 mm, and the average rainfall for this time period is 690 mm. The irrigation water used for 100% replacement of ET loss contributed sodium and bicarbonate at each irrigation (Table 3) resulting in elevated soil sodium in College Station (Table 6).

Table 6. Soil pH, electrical conductivity (EC), and plant nutrients and sodium content by region from samples collected in Sept 2007 and July 2008.

Region	pH	EC	NO3	P	K	Ca	Mg	S	Na
		S m^{-1}	- - - - - - - - - - - - mg L^{-1} - - - - - - - - - - - -						
			September 2007						
C.S.	8.4	0.012	1	18	75	1016	64	15	277
S.A.	7.2	0.065	1	18	47	611	75	9	156
			July 2008						
C.S.	8.7	0.018	3	12	94	1188	77	15	402
S.A.	7.8	0.015	4	13	152	4678	171	15	179

In 2008 in San Antonio, there was a significant season by treatment interaction effect. The K_L for St. Augustinegrass, tree, and St. Augustinegrass plus tree remained the same from early- through mid-season, and increased significantly in late-season (Table 7). The K_L of nativegrass increased sharply from early- to mid-season, and remained high into late-season (Table 7). The K_L of nativegrass plus tree was not different among seasons.

Table 7. The K_L for individual and combined plantings by region and season during 2008.

	K_L						
	CS			SA			Combined
	Early	Mid	Late	Early	Mid	Late	Regions
St. Augustine	0.26[NS]	0.24[NS]	0.15[NS]	0.48abB	0.49bcB	0.66aA	0.38NS
St. Augustine + tree	0.23	0.27	0.19	0.59aB	0.61abB	0.83aA	0.45
Tree	0.27	0.17	0.12	0.25cB	0.26cB	0.64aA	0.28
Native	0.19	0.14	0.19	0.29bcB	0.75aA	0.91aA	0.42
Native + tree	0.25	0.13	0.16	0.36bcA	0.53abA	0.60aA	0.34
seasonal mean	0.24A	0.19AB	0.16B	0.39	0.53	0.73	
year mean		0.20 B[‡]			0.54 A		

[NS] not significant

[†] Means with the same lower case letter within column are not significantly different under Scheffe's mean separation test at $p \leq 0.05$.

[‡] Means with the same upper case letter within row are not significantly different under Scheffe's mean separation test at $p \leq 0.05$.

During the early season of 2008 in San Antonio, the K_L for St. Augustinegrass plus tree was greater than all other treatments except for St. Augustinegrass (Table 7). Treatments including St. Augustinegrass transitioned quickly from winter dormancy and resumed vegetative growth rapidly in spring (Figure 5). In mid-season, the K_L for nativegrass was greater than the K_L for St. Augustinegrass and the K_L for tree alone, but was similar to St. Augustinegrass plus tree and nativegrass plus tree. By late-season, nativegrass had the largest K_L, but significant differences did not exist between treatments.

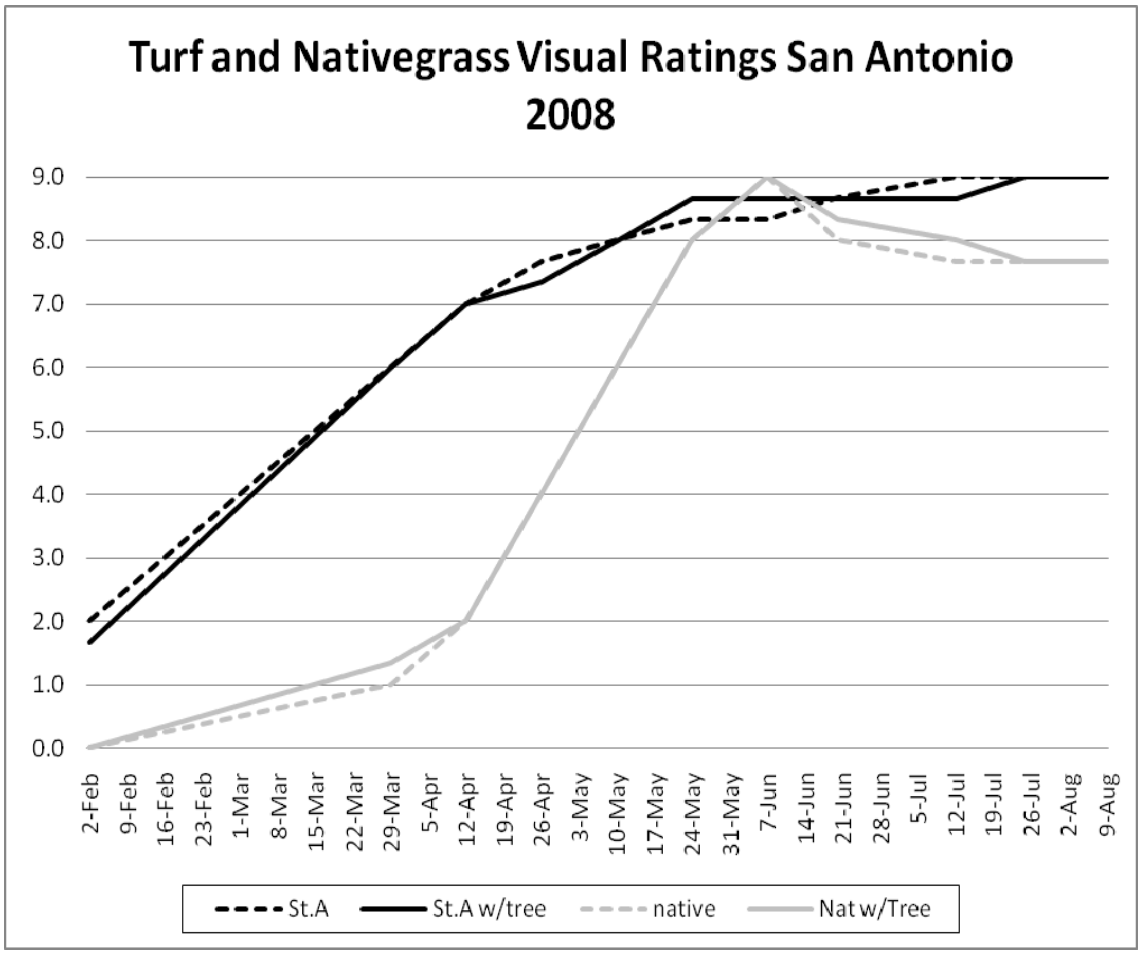

Figure 5. Visual rating (0-9) of qualitative plant health for individual and combined plantings in San Antonio during 2008.

Stomatal Conductance

The analysis of variance indicated a significant region by season by plant treatment interaction effect. Therefore, data were analyzed and presented by plant treatment. Tree stomatal conductance was affected by region (Table 8). The tree alone had a greater mean conductance in San Antonio than in College Station. This

corresponds to the K_L by region. The mean tree K_L during the entire study was 0.43 for San Antonio and 0.21 for College Station.

Table 8. The average stomatal conductance (mol m^{-2} s^{-1}) and standard deviation of tree, alone and when combined with nativegrasses and St. Augustinegrass by season and region.

	Tree	Tree with nativegrasses	Tree with St. Augustinegrass
Region			
CS	0.225±0.119 B[†]	0.240±0.114 A	0.156±0.069 B
SA	0.272±0.114 A	0.198±0.105 B	0.195±0.103 A
Season			
Early	0.205±0.085 B	0.227±0.095[NS]	0.200±0.111[NS]
Mid	0.274±0.133 A	0.217±0.123	0.173±0.087
Late	0.240±0.099 AB	0.216±0.100	0.158±0.066

[NS] not significant

[†] Stomatal conductance means with the same letter within column are not significantly different based on Scheffe's mean separation test.

When the tree was grown with St. Augustinegrass, a trend similar to the tree only treatment occurred. The mean stomatal conductance of the tree with St. Augustinegrass was greater in San Antonio than in College Station (Table 8). The mean K_L by region was 0.61 and 0.34 for San Antonio and College Station, respectively. However, the conductance of the tree with nativegrasses did not follow this regional pattern. The mean conductance for the tree growing with nativegrasses in College Station was greater than in San Antonio (Table 8).

Only the tree only treatment stomatal conductance was affected seasonally. The conductance of tree only increased by 34% from early- to mid-season, but declined by 12% in the late-season.

The analysis of variance of St. Augustinegrass treatments indicated a significant region by season by plant treatment interaction effect. Therefore, data were analyzed and presented by plant treatment (Table 9). There was a region by season interaction effect on stomatal conductance within the St. Augustinegrass alone treatment. In San Antonio, the stomatal conductance for St. Augustinegrass declined from early- to late-season by 33%. The K_L analysis for St. Augustinegrass (Tables 5 and 7) indicated an opposite seasonal trend. In College Station, mean stomatal conductance of St. Augustinegrass increased in mid-season and then sharply declined by late-season. This trend is similar to the mean K_L over seasons in College Station.

Table 9. Stomatal conductance (mol m^{-2} s^{-1}) of St. Augustinegrass alone and when combined with St. Augustinegrass by season, and region.

	St. Augustinegrass		
	Early-	Mid-	Late-
CS	0.041±0.025^{NS}	0.072±0.037^{NS}	0.022±0.014^{NS}
SA	0.082±0.073	0.065±0.036	0.055±0.024
	St. Augustinegrass with tree		
	Early-	Mid-	Late-
CS	0.048±0.018^{NS}	0.075±0.037^{NS}	0.021±0.011^{NS}
SA	0.053±0.019	0.060±0.030	0.083±0.083

^{NS} not significant

In the St. Augustinegrass with tree, stomatal conductance increased from early- to late-season in San Antonio (Table 9). This pattern is the opposite of the St. Augustinegrass alone for San Antonio. In College Station, both St. Augustinegrass treatments increased in mid-season and sharply declined by late-season.

Little bluestem stomatal conductance was affected by region and season interaction. In College Station, stomatal conductance for little bluestem increased slightly from early- to mid-season and decreased in late-season (Table 10). In San Antonio, stomatal conductance of little bluestem decreased from early- to late-season. The nativegrasses K_L did not follow a similar seasonal pattern (Table 7). Even though stomatal conductance decreased from early- to late-season, nativegrass water use remained similar or increased in the late-season most likely because of an increase in canopy size.

Table 10. Stomatal conductance (mol m^{-2} s^{-1}) of little bluestem by season and region.

	Season		
	Early	Mid	Late
Region			
CS	0.148±0.065^{NS}	0.166±0.084^{NS}	0.088±0.034^{NS}
SA	0.210±0.098	0.144±0.063	0.098±0.049

^{NS} not significant

Biomass Accumulation

Random grid placement occurred in lysimeters with St. Augustinegrass and nativegrasses. Because of the low growing dense nature of the St. Augustinegrass, each sample completely filled the 100 cm^2 grid. Due to the up-right growing habit of the

nativegrasses, most grid samples were only partially occupied with leafy tissue. Therefore in the nativegrass treatment, the bluestem mass was added to the *Muhlenbergia* mass for one composite nativegrass biomass.

The biomass accumulation data for 2007 was similar among regions and plant treatments. In 2008, the overall biomass accumulation for San Antonio was greater than for College Station (41.9 and 25.5 Mg ha^{-1}, respectively). This is similar to the differences observed for K_L by region.

Tree Caliper

The tree calipers were similar at the end of the second season. The mean tree caliper in San Antonio and College Station was 3.35 cm and 2.38 cm, respectively. Across regions, caliper means for the tree alone, tree in nativegrasses, and tree in St. Augustinegrass treatments were 3.13, 2.90, and 2.57 cm, respectively. These data are in contrast to results reported by Griffin et al. (2007) where bermudagrass had a significant effect on calipers of redbud (*Cersis Canadensis* L.) and pecan (*Carya illinoinensis* [Wangenh.] K. Koch) trees after two growing seasons. They reported that tree calipers of redbud and pecan were less when grown in conjunction with bermudagrass rather than a bare soil surface. They also found a significant effect on caliper of these tree species by Tall Fescue (*Festuca arundinacea* Schreb.) and Kentucky Bluegrass (*Poa pratensis* L.). The authors suggested that landscape tree establishment and growth is inhibited when grown in conjunction with turfgrasses, and that the inhibition is more complicated than resource competition. Griffin et al. (2007) photosynthesis data suggested there was not strong resource competition between trees and grasses, and that allelopathy may

have been influential in reducing tree growth. Tworkoski and Glenn (2001) also reported that eight different grasses reduced vegetative growth and yield of mature peach (*Prunus persica* [L.] Batch) trees.

CHAPTER III

NITROGEN, ORTHOPHOSPHATE, AND DISSOLVED ORGANIC CARBON LEACHING IN SINGLE- AND MIXED-SPECIES LANDSCAPES IN SOUTHERN TEXAS

INTRODUCTION

Leaching of nitrogen (N), orthophosphate (P), and dissolved organic carbon (DOC) from soil represents a break in their respective nutrient cycles. Nitrogen and phosphorus are plant essential elements required for many functions including amino acid, DNA, and lipid formation (Taiz and Zeiger, 2002). Both elements may need to be added through fertilization to maintain vigorous and aesthetic growth (Beard, 1973). The movement of these two elements from terrestrial to aquatic ecosystems may contribute to water pollution if mismanaged. Excess P contributes to fresh water eutrophication events, and excess nitrogen contributes to saline water eutrophication events (Gardiner and Miller, 2008). Organic carbon likewise may contribute to water quality problems by increasing biological oxygen demand in surface waters (Perry and Vanderklein, 1996) and is implicated in the formation of trihalomethanes if the surface water is abstracted for drinking water supply and chlorinated. Furthermore, loss of DOC represents a loss of terrestrial C. An understanding of nutrient removal through leaching in amenity landscapes may lead to landscape management practices that reduce impairment to ground and surface waters.

Maintaining a vigorous turfgrass cover is a way of minimizing ground water contamination from nitrate (Jiang et al., 2000). The University of Florida Extension

initiated an effort in the 1990's to promote alternative landscapes that include woody and herbaceous plant materials and minimize turfgrass use (Garner et al, 1996). This notion was conceived in an effort to reduce nitrogen leaching from urban landscapes into the environment. Erickson et al. (2001 and 2005) reported differences in nitrate and phosphorus leaching in landscapes related to species composition. Less nitrate and phosphorus leached from areas planted with St. Augustinegrass than areas planted with mixed-species ornamental plants. Erickson et al. (2001 and 2005) used common management practices in each landscape model. Amador et al. (2007) reported that unplanted-mulched areas and ground covers act as net sources of nitrate moving from landscapes into groundwater. The use of alternative plants in the landscape to reduce environmental impacts has been researched by several authors (City of Albuquerque, 2006; Hipp et al., 1993; Sacamano and Jones 1975; Xeriscape Colorado, 2005).

There is a lack of data on nitrogen and phosphorus leaching from amenity landscapes with diverse species composition, climates and different irrigation water chemistry. The objective of this study was to quantify nitrogen, orthophosphate, and dissolved organic carbon (DOC) leaching from contrasting landscape scenarios at two climatically different sites with differing irrigation water chemistry.

MATERIALS AND METHODS

Site Description

The experiment was conducted at two sites; the Texas A&M University Turfgrass Field Laboratory College Station, Texas and at a site adjacent to the San Antonio Water System Leon Creek Waste Water Treatment Facility in San Antonio,

Texas. These two sites will be referred to as the College Station region and the San Antonio region. College Station on average has greater rainfall and humidity than San Antonio (Table 11).

Table 11. Average rainfall, average relative humidity (RH), average maximum temperature (TMax), average mean temperature (TMean), average minimum temperature (TMin), and average cumulative reference evapotranspiration (RET) for CS and SA, TX

	College Station	San Antonio
Rainfall (mm)	1000	764
RH (%)	47.83	42.85
TMax (ºC)	25.8	26.6
TMean (ºC)	19.9	20.5
TMin (ºC)	14.2	14.4
RET (mm)	1430	1522

Lysimeter Construction and Sensing

Individual waterproof lysimeter containers were 1,136 L oval stock tanks (R.G. Applegate Steel Co., Saratoga, Indiana) 2.43 m long x 1.02 m wide x 0.68 m deep. Tanks bottoms were constructed from 1.0 mm galvanized steel and sides were made from 0.85 mm galvanized steel. Tanks were placed in-ground on a smooth level surface such that the tank tops were 5 cm beneath the surface grade. The bottom of the tank was filled with 1 cm diameter gravel to 5.1 cm depth. A PVC drainage pipe system was embedded in this gravel layer to allow vacuum drainage. The drainage pipe consisted of three 1.83 m long pieces of 1.27 cm diameter pipe manifold together and joined at one end with a 0.76 m tall standpipe (Figure 6). The end of each lateral was permanently capped. Three mm diameter holes were drilled in the bottom of each lateral line at 10

cm spacing to allow water to enter the pipes. The space between the individual lysimeters was 30.5 cm.

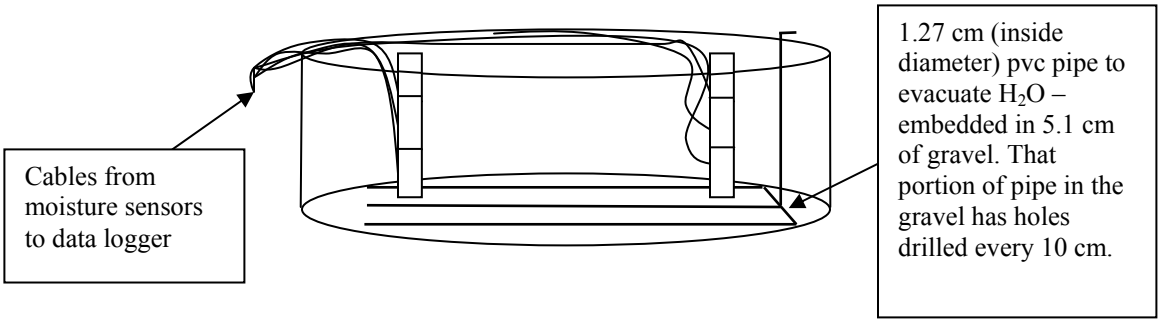

Figure 6: Schematic drawing of the lysimeter.

After the installation of the drain lines and gravel layer, soil was added in lifts. The soil was from the A horizon of the Rader fine sandy loam soil series (fine-loamy, mixed, semiactive, thermic Aquic Paleustalfs). All soil was passed through a 1.27 cm diameter screen to remove stones, roots, and other undesirable materials prior to placement in the lysimeter. Approximately 15 to 20 cm of loose soil was added and manually compacted with a hand tamper to a finished depth of 10 cm. The surface of each lift was lightly scarified with a garden rake prior to adding the next lift of soil. When the soil surface reached 10 to 15 cm below the top of the lysimeters, a 15 cm wide strip of 0.1 mm plastic was taped to the inside of the lysimeter wall using duct tape. This plastic sheet was allowed to extend horizontally toward the center of the lysimeter on top of the soil. The plastic sheet provided a mechanical barrier to reduce the potential for side wall flow and helped force downward moving water away from the side walls of

the lysimeters so that it would flow through the bulk soil (Brown et al., 1985). Continuation of soil lifts to the lysimeters brought them to filled capacity. Lysimeters for the San Antonio location were built in College Station, transported to San Antonio, and installed in-ground.

Lysimeters at each location were irrigated with a two zone in-ground automatic system. Irrigation spray heads (Toro 70 Series Bloomington, MN) were installed at 3.65 m triangulated spacing. A water meter was installed in each zone to allow measurement of total applied water. Irrigation was adjusted every 2 to 3 wk to replace 100% of calculated reference evapotranspiration minus precipitation.

Treatments

Treatments were arranged in a randomized complete block design with three replications. The plant treatments were randomly assigned to the lysimeters within each block. The following plant taxa were used: *Stenotaphrum secundatum* [Walt.] Kuntze. (St. Augustinegrass), *Quercus shumardii* Buckl. (shumard red oak), *Schizachyrium scoparium* [Michx.] Nash (little bluestem), *Muhlenbergia capillaries* [Lam.] Trin. (muhlygrass) and Cynodon dactylon *x C. transvaalensis*, Burtt-Davy (Bermudagrass 'Tifway'). Table 12 lists the plant treatment combinations.

Table 12. Plant treatment combinations

	Treatment					
	1	2	3	4	5	6
St. Augustinegrass 'Raleigh'	x	-	-	x	-	-
Shumard red oak	-	x	-	x	x	-
Nativegrasses - little bluestem & muhlygrass	-	-	x	-	x	-
Bermudagrass 'Tifway'	-	-	-	-	-	x

The bermudagrass treatment was located at the San Antonio site only. Plant installation occurred on Dec 19, 2006 and Dec 20, 2006 for the San Antonio and College Station locations, respectively. To avoid disturbing sensors and sensor cables, container-grown (11.4 L) shumard red oak trees were planted in the center of the lysimeters. Treatments receiving St. Augustinegrass and bermudagrass (All Seasons Turf Grass Inc., Brookshire, Texas) were planted with sod grown on a Katy fine-sandy loam series (fine-loamy, siliceous, thermic Aquic Paleudalf). Nativegrass treatments received nine, field-grown (3 L root ball) individual little bluestem and two, container-grown (5.7 L root ball) individual pink muhlygrass. The nativegrass plus red oak treatment received eight little bluestems and two pink muhlygrasses. Nativegrasses were spaced equidistant across the lysimeter.

Site Management

St. Augustinegrass was maintained at 5 to 7.6 cm cutting height with a frequency of every two to four weeks. The bluestem and muhlygrass (nativegrass treatment) were trimmed to 15 to 18 cm each December. The soil in the St. Augustinegrass alone treatment was sampled (0 to 15 cm depth) for laboratory analysis two to three times each year (Soil, Water, and Forage testing Lab College Station, TX)(Table 13). Based on soil analysis, a balanced fertilizer was added to all treatments during 2007 and 2008. Nitrogen at a rate of 48.8 kg ha^{-1} was applied in three separate events each year. Plant tissue analysis was conducted in July 2008 for only the St. Augustinegrass treatment. This was completed to indicate plant health and potential negative effects of soil salts.

Table 13. Regional Soil pH, electrical conductivity (EC), and plant nutrients and sodium content from samples collected in Sept 2007 and July 2008.

Region	pH	EC	NO3	P	K	Ca	Mg	S	Na
		S m^{-1}	- - - - - - - - - - - - mg L^{-1} - - - - - - - - - - - -						
			September 2007						
C.S.	8.4	0.012	1	18	75	1016	64	15	277
S.A.	7.2	0.065	1	18	47	611	75	9	156
			July 2008						
C.S.	8.7	0.018	3	12	94	1188	77	15	402
S.A.	7.8	0.015	4	13	152	4678	171	15	179

Azoxystrobin (Methyl 2-2-6-(2-cyanophenoxy) pyrimidin-4-yloxy-phenyl-3-methoxyacrylate) fungicide was applied in March 2007 at labeled rate to turfgrass treatments for brown patch (*Rhizoctonia solani*) control. Fipronil (5-amino-1-[2,6-dichloro-4-(trifluoromethyl)phenyl]-4-[(1R,S)-(trifluoromethyl)sulfinyl]-1H-pyrazole-3-carbonitrile) insecticide was applied according to label recommendation in 2007 and 2008 for red imported fire ant control. All shumard red oak trees received triforine ([N,N-bis-(l formamido-2,2,2- trichloroethyl)-piperazine) fungicide at budbreak in Mar 2008 to prevent symptoms of anthracnose. A 1 m perimeter was treated monthly with glyphosate (2-(phosphonomethylamino) acetic acid) herbicide at both locations. Lysimeters were vacuum evacuated every 2 to 4 wk to avoid saturation of the gravel layer. A 0.75 hp pump with a 1.5 cm inside diameter polyethylene hose was attached to a 20 L glass carboy. A second polyethylene hose was attached to the carboy and the pvc drainage line of the lysimeter. At each lysimeter, the pump was powered until the lysimeter stopped yielding water. Water volume was quantified, and 200 ml was retained in polyethylene bottles. Bottles were tagged with date, regional location,

lysimeter information and frozen. Leachate samples for this study were obtained from May 5, 2007 until April 28, 2008.

Irrigation Water Analysis

Irrigation water from both sites was submitted for laboratory analysis in July 2008. Results are summarized in Table 14.

Table 14. Regional irrigation water pH, electrical conductivity (EC), plant nutrients, calcium carbonate, sodium content, and sodium adsorption ratio (SAR)

Region	pH	EC	PO_4^{3-}	K^+	Ca^{2+}	Mg^{2+}	SO_4^{2-}	HCO_3^-	Na^+	SAR
		$S\ m^{-1}$	- - - - - - - - - - - - - - - -			$mg\ L^{-1}$	- - - - - - - - - - - - - - - -			
C.S.	9.09	0.089	0.1	2.0	2.0	0.5	0.6	393.4	232.0	53.7
S.A.	7.85	0.057	0.0	1.9	24.1	16.3	27.0	190.4	12.3	0.7

Chemical Analysis

After thawing, sample conductivity and pH were measured on unfiltered samples. Samples for chemical analysis were filtered through ashed (500º C for 4 h) Whatman GF/F (nominal pore size 0.7 μm) filters. Dissolved organic carbon (DOC) and total dissolved nitrogen (TDN) were measured with high temperature Pt-catalyzed combustion using a Shimadzu TOC-V_{CSH} and Shimadzu total measuring unit (TNM-1). DOC was measured as non-purgable carbon using UEPA method 415.1 which entails acidifying (2N HCl) the sample and sparging for 4 min with C-free air. Ammonium was analyzed using the phenate hypochlorite method with sodium nitroprusside enhancement (USEPA method 350.1) and nitrate was analyzed using Cd-Cu reduction (USEPA method 353.3). Alkalinity was quantified using methyl orange (USEPA method 310.2).

Alkalinity was assumed to be in the form of bicarbonate. Orthophosphate-P was quantified using the ammonium molybdate method (USEPA 365.1). All colorimetric methods were performed with a Westco Scientific Smartchem Discrete Analyzer. Dissolved organic nitrogen (DON) is the product of TDN – (NH3-N + NO3-N). NIST traceable standards and check standards were run every twelfth sample for all analyses. If percentage coefficient of variance between replicates was >5%, the sample was re-analyzed. Typically, %CV was < 1% for colorimetric analysis and < 5% for DOC and TDN analyses.

Statistical Analysis

Nutrient concentrations, leachate pH and conductivity were subjected to Proc GLM in SAS v. 9.1 (SAS Institute, 2003). One way analysis of variance (ANOVA) was applied to the leachate data to test the hypothesis that vegetative treatment had no effect on nutrient leaching among or between sites. Post hoc Tukey honestly significant difference test was applied to the data to determine significant differences among and between sites. Effects were considered statistically significant at $P \leq 0.05$. Pearson correlation analysis was applied to the nutrient data to examine correlations between nutrients that might explain leaching mechanisms.

RESULTS

Not all lysimeters produced leachate at College Station. Lysimeters 8 and 11, tree only and native plus tree respectively, produced only one sample of leachate, and lysimeter 15, nativegrasses, produced only two leachate samples over the entire year Therefore, these were removed from the analysis to remove the bias on mean annual

concentrations. Leachate samples for the first four months of the experiment (Jan through Apr) were not included in the analysis because there was a large disturbance effect shown by enhanced nitrate-N concentrations (100 to 200 mg L^{-1}). Data from May 5, 2007 to Apr 28, 2008 were used in this study.

Annual Mean Leachate Chemistry

There were significant differences in leachate chemistry by treatment and by site. Vegetation did not have an effect on annual mean leachate pH at either the College Station or San Antonio sites (Figure 7). San Antonio had significantly greater annual mean leachate pH for all treatments ($p < 0.05$) except for native grasses (Figure 7).

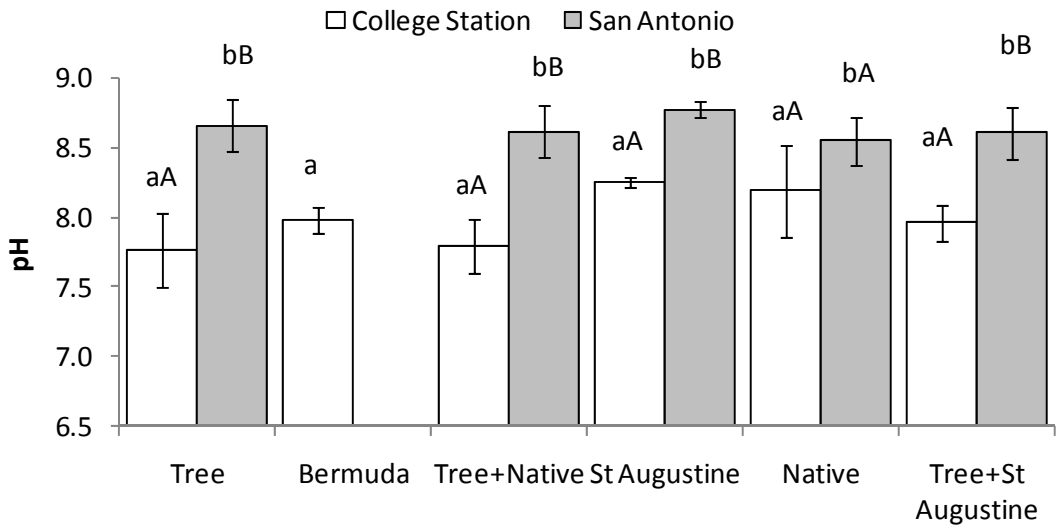

Figure 7. Annual mean pH for the two sites. Lower case letters are for differences within Site. Differences between sites are shown as differences in upper case letters. Error bars are standard deviation.

There was no significant difference in annual mean leachate conductivity within sites indicating that vegetation had no effect on conductivity of leachate solution (Figure

8). Between sites, only the treatment comprising St Augustine plus tree had a significant difference in annual mean leachate conductivity (Figure 8).

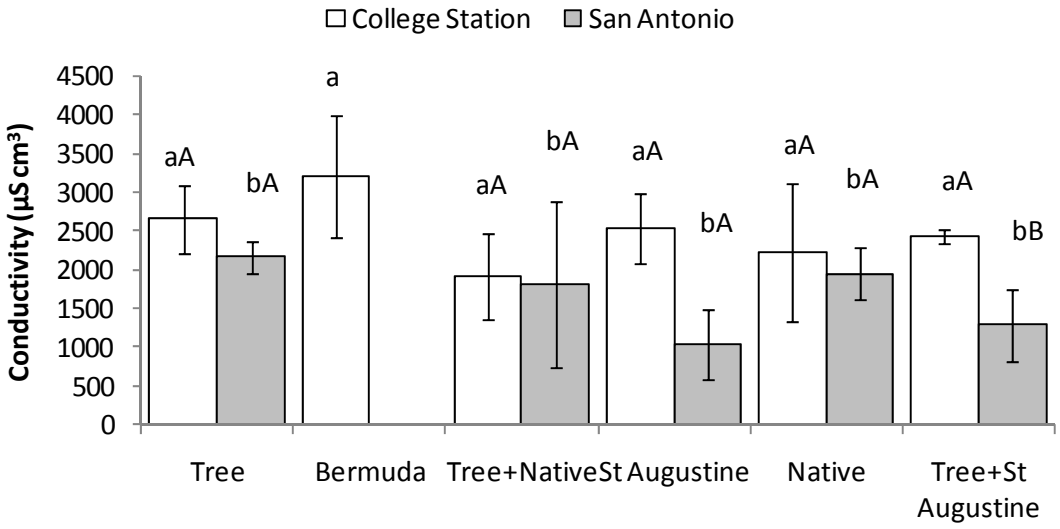

Figure 8. Annual mean conductivity for the two sites. Lower case letters are for differences within Site. Differences between sites are shown as differences in upper case letters. Error bars are standard deviation.

There was a significant difference in annual mean nitrate-N concentrations at College Station, but not at San Antonio. At College Station, the Bermudagrass treatment lost significantly lower annual mean nitrate-N concentration than the nativegrass alone or the nativegrass plus tree (Figure 9). Highest annual mean nitrate-N concentration was under the natives plus tree treatment where it was significantly greater than the tree alone, Bermuda and St. Augustine only treatments (Figure 9).

Between sites, annual mean nitrate-N concentration was significantly higher at San Antonio under the tree only treatment. There was no significant difference in annual mean nitrate-N concentration between sites for any of the other vegetation treatments.

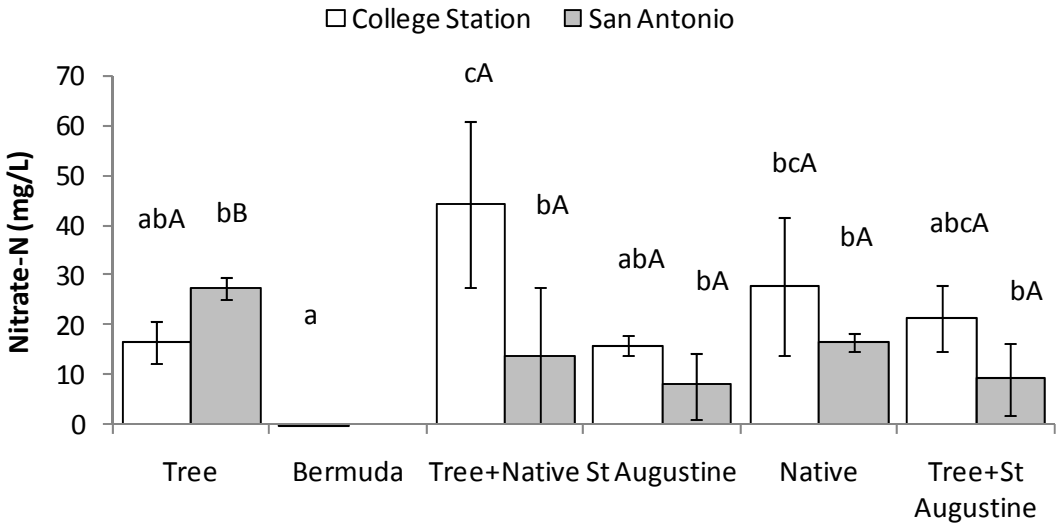

Figure 9. Annual mean leachate nitrate-N concentration for the two sites. Lower case letters are for differences within Site. Differences between sites are shown as differences in upper case letters. Error bars are standard deviation.

There was no significant effect of vegetative treatment at College Station or San Antonio for annual mean DOC concentrations. Between sites there was no significant difference in annual mean DOC concentration with the exception of the tree only treatment (Figure 10) which was significantly higher at San Antonio.

Vegetative treatment had a significant effect on annual mean DON concentration at College Station, but not at San Antonio. Bermudagrass had significantly lower DON concentration than the nativegrass plus tree treatment at College Station. Between sites the St Augustine treatment had significantly higher annual mean DON concentration at College Station compared to San Antonio (Figure 11).

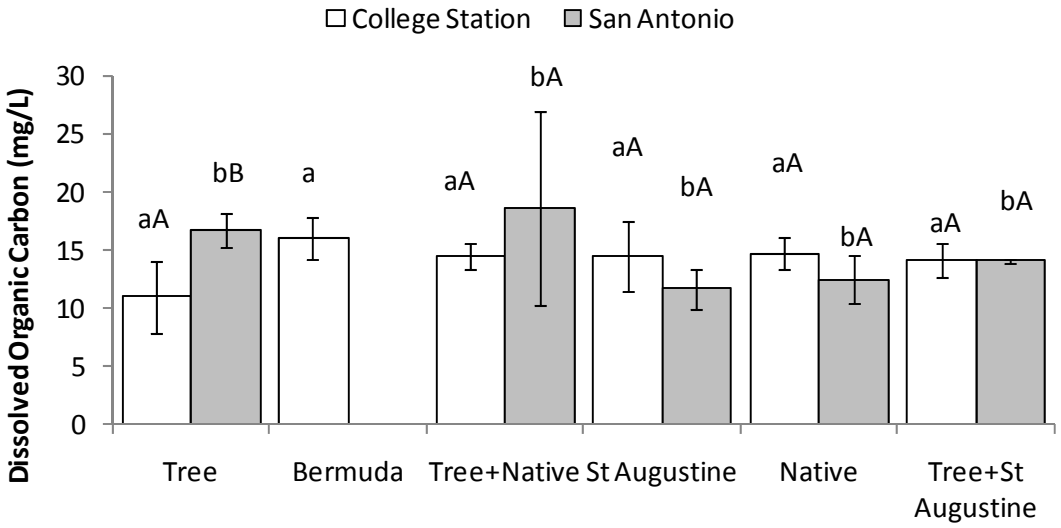

Figure 10. Annual mean leachate dissolved organic carbon concentration for the two sites. Lower case letters are for differences within Site. Differences between sites are shown as differences in upper case letters. Error bars are standard deviation.

There was no significant difference in annual mean orthophosphate-P concentrations at College Station or San Antonio by treatment type. Orthophosphate-P concentrations were significantly higher at San Antonio under the tree alone, nativegrass and St Augustine plus tree treatments (Figure 12).

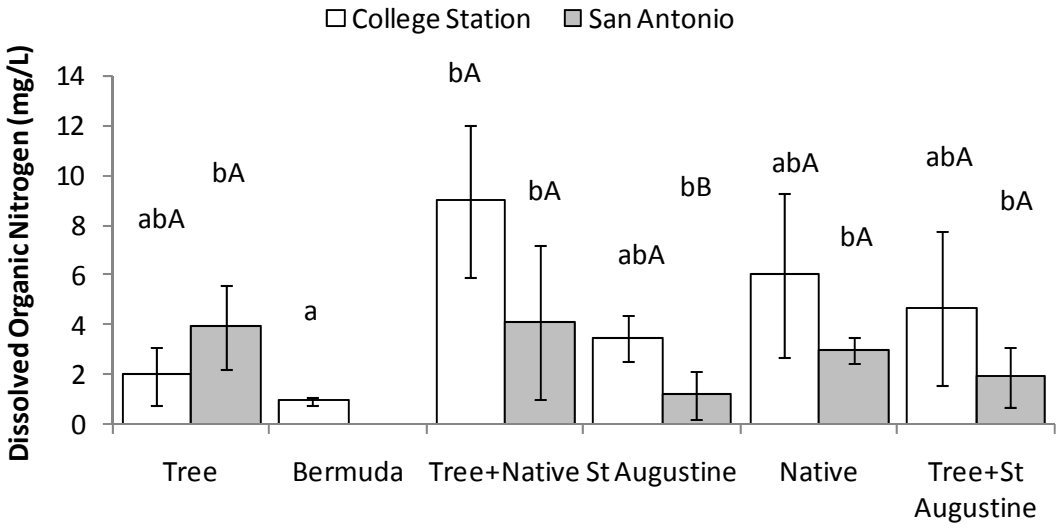

Figure 11. Annual mean leachate dissolved organic nitrogen concentration for the two sites. Lower case letters are for differences within Site. Differences between sites are shown as differences in upper case letters. Error bars are standard deviation.

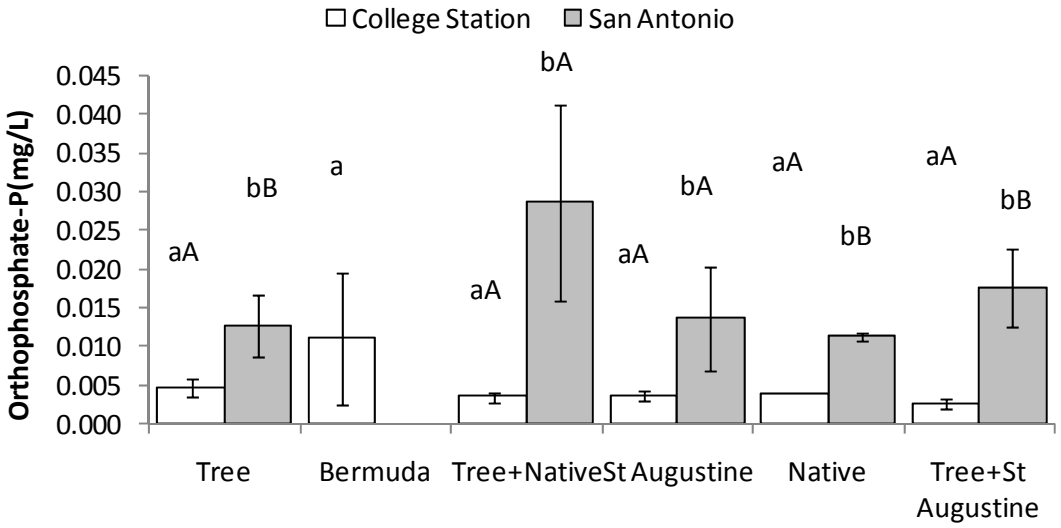

Figure 12. Annual mean leachate orthophosphate-P concentration for the two sites. Lower case letters are for differences within Site. Differences between sites are shown as differences in upper case letters. Error bars are standard deviation.

Annual mean alkalinity concentrations were not significantly different by vegetative treatment within either site. Between sites the nativegrass plus tree treatment had significantly greater annual mean alkalinity concentration at San Antonio compared to College Station (Figure 13).

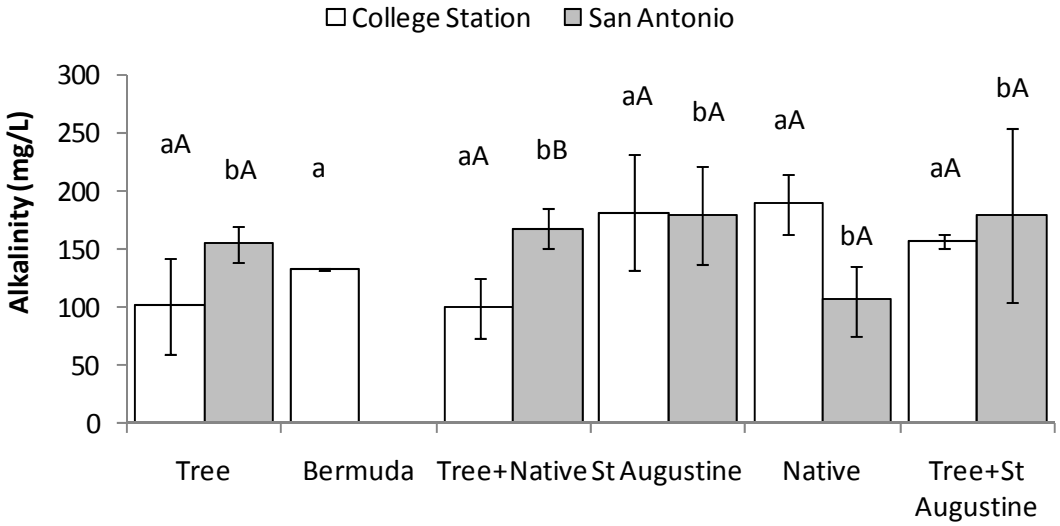

Figure 13. Annual mean leachate alkalinity concentration for the two sites. Lower case letters are for differences within Site. Differences between sites are shown as differences in upper case letters. Error bars are standard deviation.

Ammonium-N concentrations were not affected by vegetative treatment within site at College Station or San Antonio. Likewise, site was not significant under any vegetative treatment.

Relationships Between Leachate Chemistries

Ninety-three percent of the variance in annual mean nitrate-N concentration was described by DON at College Station and while a similar relationship was also apparent

at San Antonio the amount of variance explained dropped to 55% and was not significant (Figure 14). No other relationships between leachate chemistry at College Station or San Antonio were found that may offer an indication of the mechanisms resulting in leachate chemistry under these vegetative treatments.

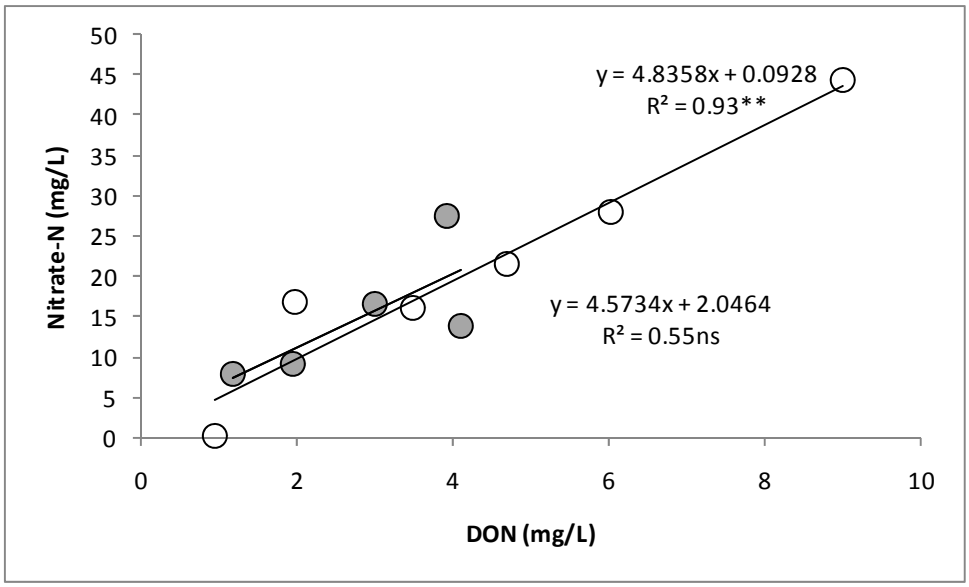

Figure 14. Relationship between nitrate-N and DON at College Station and San Antonio.

CHAPTER IV

CONCLUSIONS

LANDSCAPE COEFFICIENTS

Irrigation water, rather than precipitation, became a larger component of ET replacement in late spring and summer (Table 15). Irrigation water quality may have influenced K_L. College Station irrigation water was high in sodium and bicarbonate. San Antonio irrigation water was high in calcium and carbonate (Table 4). The effects of soil sodium on landscape plant performance in College Station are evidenced in the larger K_L and biomass accumulation in the San Antonio region. Sodium accumulation in College Station likely altered soil water potential and may have caused reduced evapotranspiration compared to San Antonio.

Table 15. Average seasonal rainfall, actual seasonal rainfall and percent variation from average rainfall during 2007 and 2008 in College Station and San Antonio, TX.

		College Station	
Season	Average (mm)	2007	2008
Early	248	223 (-10%)	181 (-25%)
Mid	270	311 (+15%)	270 (0) †
Late	225	202 (-10%)	74 (-67%)
		San Antonio	
Season	Average (mm)	2007	2008
Early	187	167 (-11%)	57 (-70%)
Mid	245	557 (+127%)	238 (-3%) ‡
Late	179	36 (-80%)	23 (-87%)

† 134 mm (50% of season) in 3 weeks of Aug

‡ 104 mm (43% of season) in 2 weeks of Aug

The decreasing K_L values with season in College Station may be due to the effects of sodium in the soil (Table 4) and plant tissue. Tissue analysis from the St. Augustinegrass treatment indicated 11,362 mg L^{-1} Na in College Station compared with 7,882 mg L^{-1} from San Antonio. Soil and plant tissue sodium levels may have affected the plants ability to take up water for transpiration and for other metabolic processes (Ben-gal and Shani, 2002; Munn, 2002). Furthermore, the average leachate per treatment was 85.8 L in San Antonio and 131.1 L in College Station. This is 53% more leachate from the College Station site even though irrigation was at 100% replacement of RET losses at both sites. This too is an indication of altered soil water use by climate region.

Leaf margin necrosis in the Shumard red oak trees in College Station was observed initially in early July 2008, and this condition continued into October (data not presented). This marginal leaf necrosis appeared somewhat symmetrical indicating a visual symptom of salt stress. Miyamoto et al. (2004) listed Shumard red oak as a salt-sensitive deciduous tree. Their study included several common tree, shrub, and grass species, and the use of salinity standards from the U.S. Salinity Laboratory classification system. St. Augustinegrass was rated as a salt tolerant (0.8 to 1.0 S m^{-1}) turfgrass. The nativegrasses *Schizachyrium scoparium* and *Muhlenbergia capillaries* were not included in the Miyamoto et al. (2004) study.

In 2008 in San Antonio, the St. Augustinegrass transitioned quickly from winter dormancy and resumed growth in early spring. This may be the cause of a larger early-season K_L in those treatments with St. Augustinegrass compared to those treatments with

nativegrasses. By mid-season, the nativegrass K_L was greater than the K_L for St. Augustine and tree only. This is probably a reflection of the increasing volume of plant canopy and subsequent increased transpirational area. The K_L for St. Augustine, tree, and St. Augustine plus tree increased significantly from mid- to late-season. Brown et al. (2001) reported similarly that bermudagrass water use increased from June to September. Saha et al. (2005) reported that St. Augustinegrass grown in pots in a greenhouse had significantly less water use in the autumn than in the summer. Carrow (1995) determined after averaging the water consumption from two growing seasons, that 'Raleigh' St. Augustine had greater water use in Sept and Oct than in Jul and Aug.

It is not known if the late-season decrease in stomatal conductance of little bluestem is related to the formation and maturation of the inflorescence, and a possible influence of elevated soil sodium in the College Station region. Winter wheat (*Triticum aestivum* L.) leaf stomatal conductance declines during flowering and seed formation (Frederick, 1997).

Stomatal conductance values were not necessarily reflective of seasonal or regional water use. Most of the species-to-species stomatal conductance comparisons were generally larger in San Antonio. This may be caused by a greater reference ET in San Antonio, and/or a soil sodium induced osmotic factor in water potential in College Station. It is possible that the soil sodium concentration in College Station reduced the stomatal conductance as well as the water use. Hubbard et al. (2001) detailed how stomatal conductance was directly proportional ($r^2>0.90$) to hydraulic conductance in

seedling *Pinus ponderosa*. Hubbard's test was performed in controlled steady-state conditions.

The overall biomass accumulation in College Station may have been affected by the presence of high soil sodium concentrations. Eom et al. (2007) found differential responses of six herbaceous perennials to soil sodium concentrations, transpiration, and reduced biomass. In general, increasing soil sodium concentrations reduced transpiration and biomass accumulation for the six groundcovers. Increasing soil sodium concentration also lowered biomass accumulation in annual ryegrass (*Lolium multiflorum* Lam.) grown in sand (Sagi et al., 1998). It is likely that elevated sodium in College Station affected biomass accumulation compared to San Antonio biomass accumulation.

Seasonal differences in plant treatment K_L's were much larger in San Antonio than the K_L's in College Station. The increase in K_L from early- to mid-season in the plant treatments in San Antonio followed a corresponding increase in evaporative demand during this time period. Some evidence now exists to potentially use reference ET data as a predictor of seasonal water demand. Also, the influence of soil sodium accumulation on water use is evident.

The literature includes several examples of crop coefficients for turfgrass as a single-species (Brown et al., 2001, Carrow, 1995, Ervin and Koski, 1998, Kim and Beard, 1998) and for woody plants as single-species (Levitt et al., 1995, Maupin and Struve, 1997, Miyamoto et al. 2004), but very few examples for mixed-species plantings. White et al. (2004) described the potential for water savings in mixed-species landscapes

by using a coefficient of 0.7. However, that study did not included field data measurements of actual water use. There is a lack of science-based information on seasonal irrigation coefficients for mixed-species landscapes. The results of this study trend towards an acceptable irrigation coefficient of 0.7 for mixed-species landscapes in southern Texas with St. Augustinegrass. St. Augustinegrass is widely used in the south in mixed-species landscapes (Saha and Trenholm, 2007). More work in landscape coefficients is needed. New studies should include other climatic regions and use of other woody plant species. Corresponding work is also needed to determine the aesthetic acceptability of the landscape plants grown under a landscape coefficient less than 1.0.

Municipalities and water planning agencies use several methods to promote water conservation among users (Barta, 2004, City of Albuquerque, 2006, Desena, 1998, Vickers, 2001). The use of a landscape coefficient for irrigating mixed-species landscapes has potential to be used in planning regional water needs. Seasonal landscape water demand could be closely predicted with a landscape coefficient, weather station data, and number of irrigated acres in the region.

The lysimeters of this study will continue for several years to provide valuable data on the contribution of the tree to total water use. As the shumard oak tree grows each successive year, it is predicted that the water demand will increase and potentially raise the landscape coefficient of the turf/tree combination. The nativegrasses potentially have higher landscape coefficients than the turfgrass or tree alone. It appears the nativegrasses are opportunistic plants in regards to water use. Further study on the

nativegrasses water use might determine if lower landscape coefficients (e.g. 0.7) are acceptable for growth and maintenance that meets a specific aesthetic level in the landscape.

In retrospect, a yearly root measurement from a 24 cm soil core would have provided information on root distribution by plant species. This would be in terms of both rooting depth and root mass per unit volume. This information would possibly be another indicator of competition between grassy and tree species. However due to moisture sensing instruments in the soil, this would severely limit accessible areas for soil sampling.

College Station water quality became a factor in plant health and potential performance in 2008. The College Station site did not have access to reverse osmosis water, or a water source of similar quality to water at the San Antonio site. The removal of the water quality factor from the College Station site would potentially allow a more reasonable comparison of landscape coefficients between the two sites. Continued soil moisture measurements at the two sites will provide needed data regarding landscape coefficients in established landscapes.

LEACHATE CHEMISTRY

The leachate samples from the initial four months after plant installation were excluded from the analysis due to a disturbance effect of the soil during excavation and lysimeter construction. The method of screening the soil during construction of lysimeters may have significantly increased the rate of mineralization and subsequent nitrate leaching. Nitrate leaching losses were probably from nitrogen mineralization

derived from the organic matter (Geron et al., 1993). Similar studies of plants have yielded results of initial disturbance effects on nutrient leaching (Easton and Petrovic, 2004). During this time period, total dissolved nitrogen concentrations in leachate ranged from 7.2 to 230 mg L^{-1}.

The cumulative plant treatment leachate averaged 85.8 L for San Antonio and 131.1 L for College Station. This occurred despite irrigation at 100% replacement of RET losses at both sites. Irrigation water, rather than precipitation, became a larger component of the replacement of RET losses in the summer and autumn months. San Antonio irrigation water is high in calcium and carbonate, and low in sodium. College Station irrigation water, high in sodium and bicarbonate, contributed to a nearly sodic soil condition. This likely caused a sodium induced osmotic effect in soil water availability, and reduced plant biomass accumulation (data not shown) compared to the San Antonio site. There was no consistent difference in leachate nutrient concentrations by plant treatment.

Mean orthophosphate-P concentrations in leachate from San Antonio were larger in each of the treatments shared between the two sites. However, the difference was only significant in tree only, nativegrass, and St. Augustine plus tree treatments. There is evidence of enhanced phosphorus dissolution in reduced soil conditions (Sims, 1998; Phillips, 1998). This could have caused greater release of soil phosphorus and subsequent leachate orthophosphate in San Antonio versus College Station. However, lysimeter management techniques were the same in San Antonio as College Station and therefore soil redox potential the same at both sites.

Phosphorus precipitates result from reaction of soil P and calcium in soils where pH is high and calcium is the dominant cation (Hons, 2004). The solubility of these precipitates is dependent on the soil pH with decreasing alkalinity allowing greater solubility of the precipitated phosphorus (Olsen and Khasawneh, 1980). Soil pH in San Antonio was consistently less alkaline than the soil in College Station (Table 12). This may indicate that more phosphorus dissolved from secondary mineral precipitates in San Antonio than in College Station. Greater amounts of soil soluble phosphorus at the San Antonio site would be a cause of greater concentrations of phosphorus in leachate compared to College Station site.

Wright et al. (2007) studied the effects of added compost on soil nutrient concentrations with St. Augustinegrass. That study found soil phosphorus was significantly correlated (0.60) with soil DOC. There is not a significant correlation between leachate DOC and leachate orthophosphate in my study.

Within each site, plant treatment had no effect on differences in leachate pH, conductivity, DOC, DON, orthophosphate-P, ammonium, or alkalinity concentrations. This is in contrast to a study by Erickson et al. (2001; 2005) in which inorganic nitrogen and total phosphorus concentrations varied by plant treatment growing on sand in south Florida. In their study, leachate was obtained from St. Augustinegrass plots and mixed-species landscape plots. For both nutrients, concentrations were less from the St. Augustinegrass plots. Their mixed-species plots contained both herbaceous perennials and woody plants. Additionally, all their data was obtained during the first year after plant installation.

In CS, there was a significant difference in nitrate concentrations among treatments. Where mean nitrate concentrations were not significantly different between bermudagrass and St. Augustinegrass only treatments, the tree plus nativegrass treatment had significantly higher nitrate than tree alone. Bowman et al., (2002) reported that 'Tifway' bermudagrass and 'Raleigh' St. Augustinegrass were the most effective of six warm season grasses at potentially reducing soil nitrate leaching. The Bowamn et al. experiment was designed however to maximize leaching from all plant treatments. Concentrations of nitrate in leaching water at CS and SA were nevertheless very high ranging from 16 to 44 mg N/L^{-1} at CS and 8 to 27 mg N/L^{-1} at SA. Organic matter in soil is the reservoir for nitrogen, vegetation can not use organic N with the exception of some amino acids and so the organic N undergoes ammonification which is available to plants through their roots. Ammonium binds tightly to soil and does not typically leach into groundwater. This is well illustrated in this study when comparing concentrations of nitrate-N and DON to ammonium-N. However, in warm, well aerated soil ammonium can be rapidly converted to nitrate which is readily leached from soils. This is thought to occur when availability of labile carbon is low. Concentrations of dissolved organic carbon were relatively low compared to other studies, particularly those describing concentrations in upper soil horizons but higher than those concentrations typically found in mineral soils at depth (e.g. Aitkenhead-Peterson et al., 2003).

Vegetation had a significant effect on DON at College Station but not San Antonio. St Augustine produced significantly higher concentrations of DON at College

Station than at San Antonio. DON concentrations were higher than observed in other studies, for example, concentrations typically range from 0.4 to 3.1 mg/L^{-1} in organic soils and 0.2 to 1.0 mg/L^{-1} in mineral soils of forests (Aitkenhead-Peterson et al. 2003). Very few studies have examined DON leaching from under turfgrass, and most that have, applied compost or manure. Nitrate and ammonium leached readily during the four months after plant installation, but soon declined as plants established. Actual field conditions and management techniques may alter the concentrations of leaching nutrients. Thus, the concentrations of nutrients may vary in more heavily fertilized or heavily irrigated situations. From a practical standpoint, careful fertilization and irrigation are needed to prevent groundwater contamination by nutrients leaching from the ornamental landscape.

A reason why significant differences did not occur in leachate chemistry among vegetative species at each site may have been the depth of the lysimeter. Leachate was collected from the saturated flow zone contained within the gravel layer rather than from the unsaturated flow zone within the soil horizon. With collections of leachate every 2-4 weeks, solution was likely in reducing rather than oxidizing conditions which may have confounded any differences I should have observed among species at each site. A solution to this would be to install tension lysimeters at several depths in the soil profile.

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APPENDIX A

SAN ANTONIO CLIMATE DATA

Date	net Radiation (MJ/m^2 d)	avg air ºC	avg rh %	avg wind m/sec	rain mm	RET mm
3/21/2007	10.74	22.50	66	2.51	0.0	2.8
3/22/2007	7.05	21.67	75	2.70	0.0	2.3
3/23/2007	6.71	21.94	77	2.32	0.0	2.0
3/24/2007	13.07	22.50	60	2.85	0.0	3.6
3/25/2007	5.57	21.11	81	2.49	0.0	1.8
3/26/2007	2.82	18.89	90	2.72	32.8	1.0
3/27/2007	10.24	20.28	73	0.72	0.0	2.0
3/28/2007	17.36	23.06	66	2.25	0.0	3.8
3/29/2007	4.39	21.94	77	2.92	0.0	1.8
3/30/2007	4.34	21.94	76	2.74	7.4	1.8
3/31/2007	20.99	19.72	42	0.84	27.7	4.1
4/1/2007	24.02	18.61	39	1.75	0.0	4.6
4/2/2007	17.03	24.17	62	1.27	0.0	3.6
4/3/2007	13.85	23.61	72	1.54	0.0	2.8
4/4/2007	12.11	18.89	58	1.68	0.0	3.0
4/5/2007	23.48	16.67	43	1.64	0.0	4.3
4/6/2007	20.78	16.11	46	2.23	0.0	4.1
4/7/2007	1.69	7.78	60	3.57	4.1	1.8
4/8/2007	11.82	5.56	74	1.34	2.5	1.5
4/9/2007	7.39	10.83	80	1.43	0.0	1.3
4/10/2007	13.6	17.50	66	0.98	0.3	2.5
4/11/2007	25.99	20.00	29	0.84	0.0	4.8
4/12/2007	23.71	17.50	53	2.11	0.0	4.6
4/13/2007	13.47	23.06	62	2.01	7.4	3.6
4/14/2007	24.27	14.44	48	1.81	1.8	4.1
4/15/2007	26.79	13.06	40	0.76	0.0	3.8
4/16/2007	19.83	14.17	58	2.11	0.0	3.6
4/17/2007	10.95	19.17	74	0.93	0.5	2.3
4/18/2007	25.63	19.17	41	0.45	0.0	4.8
4/19/2007	20.77	17.50	65	1.72	0.0	3.8
4/20/2007	21.68	21.39	62	2.35	0.0	4.3
4/21/2007	10.46	20.28	71	2.07	0.0	2.5
4/22/2007	3.78	20.28	91	1.71	0.3	1.0
4/23/2007	10.75	22.78	79	1.93	0.0	2.3
4/24/2007	3.49	22.78	88	2.62	1.5	1.3
4/25/2007	26.64	22.78	40	1.38	15.5	5.3
4/26/2007	25.75	18.33	52	1.44	0.0	4.6
4/27/2007	14.83	19.44	64	1.57	0.0	3.3
4/28/2007	11.36	21.94	75	1.56	0.0	2.5
4/29/2007	12.2	23.61	82	1.76	0.5	2.5

4/30/2007	5.91	19.44	90	2.20	18.8	1.3
5/1/2007	11.56	25.28	74	1.15	0.0	2.8
5/2/2007	6.46	22.22	87	1.22	0.8	1.5
5/3/2007	17.82	23.61	74	1.54	0.0	3.6
5/4/2007	13.48	25.00	75	1.15	0.3	3.0
5/5/2007	7.72	25.28	82	2.37	0.0	2.0
5/6/2007	6.13	25.56	85	3.56	0.0	1.8
5/7/2007	16.94	25.56	66	3.79	0.0	4.3
5/8/2007	21.89	23.89	64	3.01	3.3	4.6
5/9/2007	14.38	21.67	69	1.91	5.1	3.0
5/10/2007	23.86	21.94	60	1.07	4.3	4.6
5/11/2007	21.02	21.94	56	0.80	0.0	4.1
5/12/2007	23.91	22.50	53	0.76	0.0	4.6
5/13/2007	26.14	23.89	47	0.36	0.0	4.8
5/14/2007	26.6	23.61	47	0.97	0.0	5.1
5/15/2007	25.87	23.61	54	1.08	0.0	5.3
5/16/2007	21.65	23.89	60	1.15	0.0	4.6
5/17/2007	20.74	21.39	52	2.54	0.0	4.8
5/18/2007	20.94	20.56	54	1.25	0.0	4.3
5/19/2007	17.07	21.39	56	0.87	0.0	3.8
5/20/2007	9.21	20.56	70	0.33	0.3	2.3
5/21/2007	12.02	22.50	73	1.68	3.3	2.8
5/22/2007	19.22	23.33	63	1.43	0.0	4.3
5/23/2007	15.64	25.00	67	1.75	0.0	3.8
5/24/2007	11.73	25.56	69	2.59	0.0	3.3
5/25/2007	12.67	21.94	74	2.48	19.1	2.8
5/26/2007	15.16	23.06	75	1.23	0.5	3.0
5/27/2007	12.9	21.94	74	2.29	9.7	2.8
5/28/2007	23.8	23.61	68	0.58	0.0	4.6
5/29/2007	21.94	25.83	67	2.06	0.0	4.6
5/30/2007	24.94	26.67	65	1.33	0.0	5.3
5/31/2007	22.52	25.83	63	1.16	0.0	4.8
6/1/2007	25.69	26.39	61	1.91	0.0	5.6
6/2/2007	20.89	25.83	61	1.43	0.0	4.6
6/3/2007	24.71	26.11	60	0.55	0.5	5.1
6/4/2007	26.48	25.28	55	0.72	3.0	5.6
6/5/2007	15.81	24.44	67	0.26	9.4	3.3
6/6/2007	21.2	25.28	67	1.08	0.0	4.6
6/7/2007	21.15	28.06	68	1.32	0.0	5.1
6/8/2007	21.02	28.61	68	1.59	0.0	5.1
6/9/2007	23.75	28.06	64	1.63	0.0	5.3
6/10/2007	22.28	27.78	59	1.83	0.0	5.1
6/11/2007	27.21	27.22	56	1.26	0.0	5.8
6/12/2007	25.93	26.94	55	0.74	0.0	5.3
6/13/2007	27.08	27.22	47	0.39	0.0	5.6
6/14/2007	25.68	26.67	50	0.61	0.0	5.3
6/15/2007	22.6	27.78	56	0.91	0.0	5.1

6/16/2007	13.45	23.89	69	0.97	20.8	3.3
6/17/2007	22.38	26.39	63	0.85	0.3	4.8
6/18/2007	24.57	28.06	63	1.34	0.0	5.6
6/19/2007	22.58	28.89	62	1.64	0.5	5.3
6/20/2007	4.07	23.06	91	0.90	15.5	1.3
6/21/2007	16.81	26.39	68	1.45	3.6	3.8
6/22/2007	7.64	23.89	89	0.73	0.5	1.8
6/23/2007	14.28	24.44	74	1.38	0.0	3.0
6/24/2007	19.17	25.28	77	0.82	0.8	4.1
6/25/2007	20.02	27.50	74	1.10	8.6	4.3
6/26/2007	20.55	28.06	67	1.58	0.0	4.8
6/27/2007	18.23	27.78	62	1.42	1.3	4.3
6/28/2007	4.38	22.22	92	0.45	38.1	1.3
6/29/2007	23.02	25.56	62	0.49	0.0	4.8
6/30/2007	25.13	27.78	62	0.61	0.0	5.3
7/1/2007	16.97	26.67	74	2.59	5.1	3.8
7/2/2007	16.38	26.39	78	1.28	0.0	3.6
7/3/2007	15.97	26.11	79	1.51	3.6	3.6
7/4/2007	9.91	24.44	76	1.45	12.4	2.3
7/5/2007	19.95	26.39	66	0.51	1.5	4.1
7/6/2007	15.29	26.94	69	1.28	20.8	3.3
7/7/2007	13.34	25.00	81	0.76	22.9	2.8
7/8/2007	17.77	27.50	69	1.21	0.0	4.1
7/9/2007	22.54	28.33	68	1.46	0.0	5.1
7/10/2007	25.55	28.33	58	1.58	1.0	5.8
7/11/2007	25.27	28.33	61	0.81	0.0	5.3
7/12/2007	24.59	28.33	62	0.75	0.0	5.3
7/13/2007	26.88	28.06	56	0.97	0.0	5.8
7/14/2007	18.13	26.67	71	1.30	0.0	3.8
7/15/2007	23.51	26.94	65	1.58	2.0	5.1
7/16/2007	26.9	25.83	63	1.11	0.0	5.3
7/17/2007	12.83	25.28	85	0.88	18.5	2.8
7/18/2007	10.03	23.61	84	0.65	6.9	2.3
7/19/2007	13.11	25.28	79	1.48	0.5	2.8
7/20/2007	3.72	24.17	96	2.17	35.6	1.0
7/21/2007	8.38	26.11	83	1.40	21.6	2.0
7/22/2007	23.62	27.22	62	1.08	0.0	5.1
7/23/2007	20.7	27.50	62	0.22	0.0	4.3
7/24/2007	14.91	25.00	73	1.17	39.6	3.0
7/25/2007	4.28	21.94	93	0.81	43.9	1.0
7/26/2007	11.62	24.17	85	0.39	0.8	2.5
7/27/2007	21.43	26.11	68	0.46	0.0	4.6
7/28/2007	20.71	26.67	67	0.66	0.0	4.3
7/29/2007	11.69	26.94	73	0.23	0.0	2.8
7/30/2007	20.09	28.33	63	0.41	0.0	4.6
7/31/2007	21.34	28.06	63	0.74	0.0	4.6
8/1/2007	25.82	28.61	59	0.39	0.0	5.3
8/2/2007	23.24	28.33	58	0.89	0.0	5.1

8/3/2007	19.71	27.50	68	1.59	0.0	4.3
8/4/2007	22.86	28.06	57	0.60	0.0	4.8
8/5/2007	22.9	28.06	59	0.94	0.0	5.1
8/6/2007	24.89	28.33	58	1.01	0.0	5.6
8/7/2007	23.51	28.61	60	0.91	0.0	5.3
8/8/2007	23.89	28.89	53	1.23	0.0	5.3
8/9/2007	24.41	28.06	50	1.10	0.0	5.3
8/10/2007	23.4	27.50	58	0.44	0.0	4.8
8/11/2007	24.81	28.33	53	0.92	0.0	5.3
8/12/2007	24.25	29.17	50	1.03	0.0	5.3
8/13/2007	22.82	29.44	39	1.29	0.0	5.3
8/14/2007	19.01	28.33	45	0.63	0.0	4.3
8/15/2007	19.63	28.33	52	1.55	0.0	4.8
8/16/2007	3.85	24.44	88	0.35	147.3	1.3
8/17/2007	19.27	28.89	65	1.61	0.8	4.6
8/18/2007	21.3	28.89	62	1.56	0.0	5.1
8/19/2007	22.6	28.61	61	1.16	0.0	5.1
8/20/2007	21.35	28.61	64	0.99	0.0	4.8
8/21/2007	18.84	26.94	70	1.27	6.9	4.1
8/22/2007	13.62	27.22	76	0.36	0.5	3.0
8/23/2007	17.03	28.33	68	1.10	6.1	3.8
8/24/2007	22.72	28.33	61	0.73	0.5	4.8
8/25/2007	22.21	27.78	59	0.94	0.0	4.8
8/26/2007	22.39	27.22	63	1.20	0.0	4.8
8/27/2007	22.46	26.94	61	0.99	0.0	4.8
8/28/2007	19.04	27.50	61	0.40	0.0	4.1
8/29/2007	0	12.78	0	0.00	0.0	1.0
8/30/2007	0	12.78	0	0.00	0.0	1.0
8/31/2007	0	12.78	0	0.00	12.4	0.8
9/1/2007	0	12.78	0	0.00	0.3	1.0
9/2/2007	0	12.78	0	0.00	0.0	1.0
9/3/2007	0	12.78	0	0.00	0.3	1.0
9/4/2007	7.96	25.28	83	0.51	41.9	2.0
9/5/2007	18.47	26.67	72	0.78	0.3	3.8
9/6/2007	21.85	27.50	64	1.32	0.0	4.6
9/7/2007	23.08	27.78	62	0.83	0.0	4.8
9/8/2007	22.4	28.89	60	0.85	0.0	4.8
9/9/2007	21.2	28.06	59	0.73	0.0	4.6
9/10/2007	19.44	27.22	59	0.85	0.0	4.1
9/11/2007	12	24.72	79	1.12	0.0	2.5
9/12/2007	20.65	25.56	57	0.66	0.0	4.3
9/13/2007	17.64	25.56	56	0.61	0.0	3.6
9/14/2007	21.96	27.22	52	0.81	0.0	4.6
9/15/2007	19.57	26.39	56	1.33	0.0	4.1
9/16/2007	19.64	25.28	59	0.99	0.0	4.1
9/17/2007	14.86	25.83	66	0.99	0.0	3.3
9/18/2007	19.56	28.06	57	1.12	0.0	4.3
9/19/2007	14.7	27.50	56	1.81	3.3	3.6

9/20/2007	20.72	26.11	53	0.80	0.0	4.3
9/21/2007	21.17	25.00	52	0.46	0.0	3.8
9/22/2007	18.43	25.28	54	0.69	0.0	3.6
9/23/2007	21.31	23.89	43	0.65	0.0	4.1
9/24/2007	20.26	24.72	46	1.00	0.0	4.1
9/25/2007	21.59	24.17	50	0.53	0.0	4.1
9/26/2007	19.44	27.50	53	0.44	0.0	3.8
9/27/2007	18.48	27.78	49	0.65	0.0	3.8
9/28/2007	18.92	26.67	47	1.60	0.0	4.6
9/29/2007	12.54	25.28	73	1.08	0.3	2.8
9/30/2007	17.01	26.94	53	0.53	0.0	3.8
10/1/2007	16.26	26.94	66	0.29	0.0	3.3
10/2/2007	16.92	26.94	54	0.34	0.0	3.6
10/3/2007	18.93	25.28	51	0.52	0.0	3.6
10/4/2007	20.36	23.61	40	1.07	0.0	3.8
10/5/2007	17.97	24.72	51	0.65	0.0	3.3
10/6/2007	19.14	25.56	48	0.76	0.0	3.8
10/7/2007	15.41	25.00	51	0.64	0.0	3.3
10/8/2007	14.12	27.22	61	1.54	2.0	3.3
10/9/2007	15.07	25.83	62	1.06	0.0	3.0
10/10/2007	17.13	26.11	51	0.92	0.0	3.8
10/11/2007	15.06	25.00	51	0.65	0.0	3.0
10/12/2007	18.81	23.06	39	0.95	0.0	3.6
10/13/2007	18.01	22.78	47	0.99	0.0	3.8
10/14/2007	15.82	25.83	51	1.10	0.0	3.8
10/15/2007	14.54	26.67	47	0.60	0.0	3.6
10/16/2007	6.02	22.22	86	2.49	4.6	1.5
10/17/2007	17.33	26.94	39	0.95	0.0	3.6
10/18/2007	13.97	24.44	49	0.53	0.0	2.8
10/19/2007	19.14	20.83	20	0.59	0.0	3.3
10/20/2007	18.32	21.67	32	0.96	0.0	3.8
10/21/2007	17.06	22.22	45	1.18	0.0	3.6
10/22/2007	8.77	16.11	43	1.71	9.9	3.0
10/23/2007	19.1	14.44	18	1.31	0.0	3.3
10/24/2007	18.51	18.33	23	1.65	5.8	3.8
10/25/2007	19.14	14.17	18	1.19	0.0	2.8
10/26/2007	18.61	14.44	25	0.51	0.0	2.5
10/27/2007	18.42	15.28	24	1.60	0.0	3.3
10/28/2007	17.86	15.56	35	1.16	0.0	3.0
10/29/2007	17.52	15.56	37	0.95	0.0	2.5
10/30/2007	17.5	15.28	38	0.68	0.0	2.3
10/31/2007	16.49	16.67	43	0.49	0.0	2.3
11/1/2007	16.7	18.33	37	0.43	0.0	2.3
11/2/2007	16.88	17.78	43	0.41	0.0	2.5
11/3/2007	14.28	20.28	45	0.57	0.0	2.3
11/4/2007	15.07	19.17	41	0.45	0.0	2.3
11/5/2007	16.18	22.22	39	0.97	0.0	3.0
11/6/2007	4.48	16.67	33	0.75	0.0	1.8

11/7/2007	3.59	13.06	29	1.11	0.0	2.0
11/8/2007	11.77	17.78	51	0.64	0.0	2.0
11/9/2007	14.91	21.39	39	0.76	0.0	2.5
11/10/2007	12.09	24.44	49	1.49	0.0	3.0
11/11/2007	13.54	22.78	48	1.06	0.0	3.0
11/12/2007	9.14	21.67	60	0.77	0.0	2.0
11/13/2007	11.37	23.61	52	0.58	0.0	2.0
11/14/2007	14.88	24.17	33	0.71	0.0	3.3
11/15/2007	15.32	12.50	15	2.01	0.0	3.3
11/16/2007	15.22	11.94	18	0.76	0.0	2.3
11/17/2007	3.86	18.06	82	0.23	0.0	1.0
11/18/2007	7.32	19.17	83	1.23	1.3	1.3
11/19/2007	8.1	20.00	64	0.25	0.0	1.5
11/20/2007	9.07	23.89	58	1.15	0.0	2.0
11/21/2007	13.63	22.78	37	0.79	0.0	3.3
11/22/2007	5.8	9.72	44	1.71	0.0	2.0
11/23/2007	3.82	6.94	52	2.76	0.0	1.5
11/24/2007	2.12	5.83	94	1.26	5.1	0.5
11/25/2007	4.85	5.28	74	1.32	3.6	0.8
11/26/2007	14.74	10.28	31	0.71	0.0	1.8
11/27/2007	13.46	9.17	45	0.71	0.0	1.5
11/28/2007	12.47	11.67	55	0.93	0.0	1.5
11/29/2007	13.02	15.00	41	0.42	0.0	1.8
11/30/2007	4.26	17.22	75	0.99	0.0	1.3
12/1/2007	3.19	21.67	73	2.02	0.0	1.5
12/2/2007	9.55	21.94	27	1.47	0.0	2.5
12/3/2007	14.64	10.56	18	1.55	0.0	2.3
12/4/2007	14.7	10.00	20	0.72	0.0	1.8
12/5/2007	14.49	14.44	21	0.34	0.0	1.5
12/6/2007	10.9	16.67	54	1.13	0.0	2.3
12/7/2007	9.53	23.61	54	0.77	0.0	2.3
12/8/2007	7.78	23.61	59	1.32	0.0	2.3
12/9/2007	6.83	19.72	58	2.50	0.0	2.8
12/10/2007	3.48	11.11	93	3.20	0.0	0.5
12/11/2007	4.67	21.67	63	1.40	0.0	2.0
12/12/2007	1.48	11.94	89	1.75	1.5	0.8
12/13/2007	4.86	11.39	63	0.43	0.0	1.0
12/14/2007	1.35	12.78	77	0.98	3.0	0.8
12/15/2007	14.59	9.17	31	2.86	0.3	2.5
12/16/2007	14.91	4.44	23	0.74	0.0	1.3
12/17/2007	13.75	5.83	30	0.87	0.0	1.5
12/18/2007	13.53	15.00	40	0.63	0.0	1.8
12/19/2007	3.91	14.72	75	0.20	0.0	0.8
12/20/2007	14.68	15.56	13	1.55	0.0	3.0
12/21/2007	12.53	13.61	19	1.17	0.0	2.8
1/1/2008	14.39	7.78	36	0.82	0.0	1.8
1/2/2008	10.22	6.67	55	2.36	0.0	1.5

1/3/2008	2.7	10.00	60	3.44	12.2	1.3
1/4/2008	12.87	12.78	62	2.26	4.1	1.8
1/5/2008	13.25	16.67	36	0.45	0.0	2.0
1/6/2008	1.46	11.67	84	1.57	0.5	0.8
1/7/2008	14.49	11.94	32	2.45	0.0	2.5
1/8/2008	14.86	7.78	28	1.05	0.0	1.8
1/9/2008	13.25	8.89	30	1.95	0.0	2.3
1/10/2008	12.92	9.44	48	1.22	0.0	2.0
1/11/2008	15.26	10.56	17	0.71	0.0	1.8
1/12/2008	12.58	12.78	14	2.38	0.0	2.8
1/13/2008	15.92	7.78	18	1.81	0.0	2.3
1/14/2008	6.35	5.83	27	1.15	0.0	1.5
1/15/2008	1.65	9.17	54	0.95	3.8	1.0
1/16/2008	5.11	8.89	80	0.37	0.3	0.8
1/17/2008	4.83	4.72	40	1.95	0.0	1.3
1/18/2008	1.66	3.89	47	0.88	1.8	0.8
1/19/2008	16.57	6.11	29	2.00	0.0	2.0
1/20/2008	16.53	3.89	34	1.37	0.0	2.5
1/21/2008	2.38	11.94	85	1.33	1.8	0.8
1/22/2008	1.2	10.00	62	1.67	0.0	1.0
1/23/2008	2.68	5.83	68	1.69	2.3	1.0
1/24/2008	1.77	5.56	94	1.17	18.3	0.5
1/25/2008	2.61	5.83	59	1.62	2.5	1.0
1/26/2008	15.74	14.17	30	0.57	0.0	2.0
1/27/2008	13.94	13.06	38	0.94	0.0	2.3
1/28/2008	6.82	18.89	52	0.99	0.3	1.8
1/29/2008	12.82	17.78	18	2.70	0.0	4.6
1/30/2008	9.37	6.67	32	0.97	0.0	2.0
1/31/2008	17.77	10.28	12	3.01	0.3	3.8
2/1/2008	16.44	6.67	15	1.10	0.0	2.5
2/2/2008	16.53	13.33	45	1.01	0.0	2.8
2/3/2008	10.91	22.78	42	0.77	0.0	2.8
2/4/2008	9.87	24.44	43	1.69	0.0	3.6
2/5/2008	13.69	21.94	21	2.96	0.0	4.6
2/6/2008	19.3	11.94	14	1.86	0.0	3.6
2/7/2008	19.04	11.67	13	1.71	0.0	3.3
2/8/2008	18.75	14.17	20	0.94	0.0	2.8
2/9/2008	16.19	18.61	28	2.09	0.0	3.6
2/10/2008	9.31	18.33	57	2.19	0.0	2.5
2/11/2008	8.3	20.00	69	1.27	0.0	2.0
2/12/2008	11.86	15.56	26	2.09	0.0	2.8
2/13/2008	20.14	10.83	14	0.92	0.0	3.0
2/14/2008	15.1	13.89	43	1.41	0.0	3.3
2/15/2008	4.07	17.78	89	1.51	0.0	1.0
2/16/2008	4.74	13.61	47	2.58	0.0	2.0
2/17/2008	20.75	15.83	17	1.92	0.3	5.1
2/18/2008	20.4	12.78	31	1.41	0.0	3.6
2/19/2008	13.18	11.94	38	1.26	0.0	2.5

2/20/2008	8.58	20.56	62	0.55	0.0	1.8
2/21/2008	14.8	21.67	33	0.71	0.0	3.6
2/22/2008	20.68	17.50	27	2.25	0.0	4.6
2/23/2008	15.44	16.11	44	1.19	0.0	3.3
2/24/2008	21.94	21.67	12	1.66	0.0	4.3
2/25/2008	18.51	22.22	18	1.21	0.0	4.8
2/26/2008	22.16	15.00	17	2.95	0.0	5.6
2/27/2008	23.04	9.17	15	0.77	0.0	3.0
2/28/2008	22.19	13.33	29	1.41	0.0	4.3
2/29/2008	14.25	20.28	45	1.97	0.0	3.8
3/1/2008	12.37	20.83	53	1.70	0.0	3.0
3/2/2008	8.28	22.22	63	2.42	0.0	3.0
3/3/2008	17.86	12.78	39	3.63	1.3	4.3
3/4/2008	24.05	10.56	11	1.64	0.0	4.3
3/5/2008	23.19	13.89	19	0.89	0.0	4.6
3/6/2008	3.34	10.28	79	2.97	17.0	1.3
3/7/2008	22.61	9.44	17	3.90	0.0	4.3
3/8/2008	24.32	9.17	16	0.82	0.0	4.1
3/9/2008	6.76	13.06	61	2.56	0.0	2.3
3/10/2008	5.27	12.78	83	2.00	14.7	1.3
3/11/2008	23.39	13.61	28	1.20	0.0	3.6
3/12/2008	23.31	14.72	26	0.95	0.0	4.1
3/13/2008	15.69	20.83	38	0.96	0.0	3.6
3/14/2008	24.03	26.39	9	2.00	0.0	5.8
3/15/2008	25.05	22.50	12	1.37	0.0	6.9
3/16/2008	8.22	20.28	64	3.99	0.0	3.3
3/17/2008	12.2	24.44	65	4.64	0.0	3.8
3/18/2008	12.78	18.89	48	3.93	2.3	4.1
3/19/2008	25.47	14.44	15	2.76	0.0	5.1
3/20/2008	25.89	13.06	16	1.03	0.0	4.3
3/21/2008	24.39	17.22	23	0.81	0.0	4.3
3/22/2008	23.81	18.06	40	1.48	0.0	4.1
3/23/2008	17.23	17.50	26	2.31	0.0	4.8
3/24/2008	23.91	16.39	27	1.95	0.0	4.8
3/25/2008	20.57	16.39	45	1.40	0.0	4.1
3/26/2008	23.69	24.17	37	1.85	0.0	5.8
3/27/2008	16.21	24.17	44	1.73	0.0	4.6
3/28/2008	6.96	20.28	68	1.49	0.3	2.0
3/30/2008	10.18	25.00	62	1.39	4.3	3.0
3/31/2008	7.4	23.89	76	1.16	1.0	2.0
4/1/2008	15.48	24.17	53	2.22	0.0	4.1
4/2/2008	8.39	21.11	69	2.07	0.0	2.8
4/3/2008	10.45	24.72	63	1.10	0.0	3.0
4/4/2008	18.02	19.72	37	1.29	0.0	4.1
4/5/2008	27.53	17.50	22	0.66	0.0	5.1
4/6/2008	24.78	20.83	45	0.69	0.0	4.3
4/7/2008	21.86	25.28	36	1.68	0.0	5.6
4/8/2008	19.97	26.39	43	1.09	0.0	5.3

4/9/2008	6.98	24.44	75	3.22	0.0	2.3
4/10/2008	25.71	25.00	27	1.43	2.0	5.6
4/11/2008	26.92	23.61	15	0.88	0.0	6.4
4/12/2008	26.42	17.50	23	2.31	0.0	5.6
4/13/2008	28.56	16.11	14	1.29	0.0	5.3
4/14/2008	28.73	15.00	19	0.68	0.0	4.6
4/15/2008	28.21	16.11	26	1.31	0.0	5.3
4/16/2008	18.67	18.89	50	2.00	0.0	4.3
4/17/2008	25.38	22.50	42	1.89	7.6	5.8
4/18/2008	28.93	18.61	24	1.80	11.9	5.3
4/19/2008	29.27	18.89	21	0.94	0.0	5.6
4/20/2008	12.61	20.56	56	1.43	0.0	3.3
4/21/2008	8.3	24.44	69	0.98	0.0	2.3
4/22/2008	19.97	26.67	56	1.04	0.0	4.6
4/23/2008	13.88	26.94	45	2.53	0.0	4.8
4/24/2008	17.28	25.56	58	1.14	0.0	4.3
4/25/2008	9.32	24.44	73	1.20	9.9	2.5
4/26/2008	25.24	23.06	60	2.41	2.3	4.8
4/27/2008	18.51	19.17	55	2.13	0.5	3.8
4/28/2008	29.4	17.22	24	0.40	0.0	4.6
4/29/2008	29.88	16.94	22	1.03	0.0	5.6
4/30/2008	26.8	21.11	49	1.58	0.0	5.6
5/1/2008	16.17	26.67	52	1.41	0.0	4.6
5/2/2008	21.87	27.50	31	1.48	0.0	5.6
5/3/2008	27.13	22.78	28	2.45	0.0	6.6
5/4/2008	17.6	21.11	45	2.98	0.0	4.8
5/5/2008	15.51	26.39	50	2.47	0.0	5.1
5/6/2008	17.42	26.67	51	1.79	0.0	4.8
5/7/2008	19.57	24.72	15	1.37	0.0	5.6
5/8/2008	28.85	23.89	23	0.90	0.0	6.1
5/9/2008	25.38	27.50	46	1.00	0.0	5.8
5/10/2008	21.45	30.00	46	0.99	0.0	5.1
5/11/2008	23.66	23.89	19	2.95	0.0	6.9
5/12/2008	9.64	23.06	44	2.14	0.0	4.1
5/13/2008	17.54	28.33	54	1.88	0.0	5.1
5/14/2008	19.46	26.11	58	2.56	1.3	5.1
5/15/2008	22.01	23.33	54	1.95	10.4	4.8
5/16/2008	24.12	22.78	36	2.48	2.3	5.6
5/17/2008	20.93	21.67	47	0.94	0.3	4.1
5/18/2008	27.86	23.61	28	0.39	0.0	5.6
5/19/2008	29.15	25.00	22	0.55	0.0	5.8
5/20/2008	28.69	28.06	26	0.69	0.0	6.4
5/21/2008	25.51	28.61	36	1.19	0.3	6.6
5/22/2008	20.4	28.89	48	1.60	0.0	6.1
5/23/2008	25.28	31.39	43	1.77	0.0	7.6
5/24/2008	24.23	30.83	42	1.49	0.0	7.1
5/25/2008	21.35	31.11	42	1.82	0.0	6.6
5/26/2008	21.12	30.00	48	1.90	0.0	6.1

5/27/2008	23.79	30.28	38	1.92	0.0	6.9
5/28/2008	23.85	28.89	34	1.65	0.0	6.1
5/29/2008	23.03	28.06	40	0.79	0.0	5.6
5/30/2008	26.53	27.78	32	0.78	0.0	6.1
5/31/2008	26.38	29.44	34	0.98	0.0	6.6
6/1/2008	27.9	30.28	29	1.33	0.0	7.4
6/2/2008	25.82	30.83	33	1.17	0.0	7.1
6/3/2008	28.3	30.56	30	1.90	0.0	7.9
6/4/2008	24.62	30.00	38	1.84	0.0	7.4
6/5/2008	12.46	30.00	54	2.86	0.0	5.3
6/6/2008	19.06	30.83	46	1.97	0.0	6.1
6/7/2008	20.24	30.56	43	2.08	0.0	6.4
6/8/2008	24.31	30.28	41	1.93	0.0	6.9
6/9/2008	26.07	30.56	34	1.57	0.0	7.4
6/10/2008	22.79	31.11	34	0.87	0.0	6.4
6/11/2008	24.88	29.72	35	1.52	0.0	6.9
6/12/2008	24.49	29.72	33	1.42	0.0	6.9
6/13/2008	25.65	30.83	34	1.10	0.0	6.9
6/14/2008	21.81	30.56	35	0.73	0.0	5.8
6/15/2008	27.3	29.72	32	0.88	0.0	6.6
6/16/2008	26.71	30.28	30	1.01	5.6	7.1
6/17/2008	25.18	30.83	32	1.08	0.0	6.6
6/18/2008	26.01	30.28	29	0.63	0.0	6.1
6/19/2008	28.29	30.28	25	0.93	0.0	7.4
6/20/2008	20.78	29.44	41	0.99	0.0	5.6
6/21/2008	22.65	28.89	34	1.20	0.0	5.3
6/22/2008	25.38	28.89	26	1.31	0.0	6.1
6/23/2008	26.11	28.89	26	1.38	0.0	6.6
6/24/2008	23.98	30.00	32	1.42	0.0	6.6
6/25/2008	25.68	30.28	32	1.43	0.0	6.9
6/26/2008	25.31	30.56	33	1.60	0.0	6.9
6/27/2008	24.39	30.83	32	1.73	0.0	7.1
6/28/2008	26.42	30.28	35	1.45	0.0	7.1
6/29/2008	21.86	30.00	33	1.01	0.0	6.1
6/30/2008	20.69	30.56	34	1.34	0.0	5.8
7/1/2008	18.41	27.50	38	0.97	1.5	4.6
7/2/2008	18.65	25.28	62	1.00	0.5	4.1
7/3/2008	17.47	26.11	59	1.06	7.1	4.1
7/4/2008	19.97	25.56	62	0.31	4.8	4.3
7/5/2008	23.51	26.11	52	0.99	0.3	5.1
7/6/2008	22.89	26.67	43	1.20	0.5	5.6
7/7/2008	11.29	26.94	58	0.57	18.8	3.3
7/8/2008	15.89	26.67	70	0.64	10.7	3.8
7/9/2008	23.65	28.33	49	1.59	4.1	5.6
7/10/2008	25.14	28.61	42	0.86	0.0	6.1
7/11/2008	25.2	29.17	45	1.44	0.0	6.4
7/12/2008	27.55	28.61	44	0.93	0.0	6.4
7/13/2008	25.81	29.44	43	0.39	0.0	5.6

7/14/2008	28.31	29.72	30	0.75	0.0	6.4
7/15/2008	27.41	30.28	33	0.93	0.0	6.6
7/16/2008	22.05	29.17	34	0.95	0.0	5.6
7/17/2008	23.42	29.44	34	0.89	0.0	5.8
7/18/2008	25.71	29.17	33	0.62	0.0	6.1
7/19/2008	23.8	29.17	32	1.09	0.0	5.8
7/20/2008	23.09	28.61	38	0.88	0.0	5.6
7/21/2008	25.93	30.00	23	0.79	0.0	6.1
7/22/2008	26.19	28.61	33	1.56	0.0	7.1
7/23/2008	15.16	29.17	53	3.95	0.0	5.8
7/24/2008	4	24.17	81	3.01	69.3	1.8
7/25/2008	23.39	28.89	55	2.11	0.0	5.8
7/26/2008	25.88	29.44	46	0.81	0.0	5.8
7/27/2008	27.54	28.61	44	0.68	0.0	6.1
7/28/2008	25.48	28.89	48	0.97	0.0	5.8
7/29/2008	25.04	28.06	48	0.87	0.0	5.8
7/30/2008	21.29	28.61	52	0.69	0.0	4.8
7/31/2008	25.08	30.00	50	0.84	0.0	5.8
8/1/2008	23	29.72	49	0.80	0.0	5.3
8/2/2008	24.12	30.28	42	0.71	0.0	5.6
8/3/2008	26.5	30.28	36	0.68	0.0	5.8
8/4/2008	25.3	29.17	35	1.00	0.0	5.3
8/5/2008	15.1	28.61	47	0.77	7.6	3.6
8/6/2008	24.75	29.17	49	0.98	0.0	5.8
8/7/2008	25.61	29.72	39	1.22	0.0	6.1
8/8/2008	26.2	30.00	35	0.61	0.0	5.8
8/9/2008	26.46	28.89	39	0.89	0.0	6.1
8/10/2008	25.64	30.28	38	0.91	0.0	6.4
8/11/2008	20.57	30.56	44	1.27	0.0	5.3
8/12/2008	6.71	25.83	75	0.36	6.9	1.8
8/13/2008	24.75	29.72	32	1.02	0.3	5.8
8/14/2008	24.1	30.28	31	0.83	0.0	5.8
8/15/2008	18.77	30.28	42	0.48	0.0	4.8
8/16/2008	19.86	28.89	44	1.36	0.8	5.6
8/17/2008	10.31	25.56	77	0.97	7.6	2.5
8/18/2008	6.47	24.44	89	0.39	16.8	1.5
8/20/2008	24.43	26.94	60	0.44	49.3	4.8
8/21/2008	19.96	28.33	59	0.70	0.0	4.3
8/22/2008	12.57	27.78	71	1.53	0.0	3.0
8/23/2008	11.39	26.39	72	1.22	22.1	2.8
8/24/2008	21.21	26.67	67	0.51	0.0	4.3
8/25/2008	24.08	28.33	57	0.22	0.0	4.8
8/26/2008	23.14	28.06	58	0.56	0.0	4.8
8/27/2008	21.37	27.78	60	0.47	0.0	4.6
8/28/2008	20.42	28.06	55	0.60	0.0	4.6
8/29/2008	11.58	26.94	74	0.07	0.3	2.5
8/30/2008	19.77	27.22	57	0.88	0.0	4.3
8/31/2008	22.6	26.94	54	0.49	1.0	4.6

9/1/2008	23.15	28.61	45	0.38	0.0	4.8
9/2/2008	23.54	29.17	47	0.25	0.0	4.8
9/3/2008	21.91	28.89	44	0.79	0.0	4.8
9/4/2008	22.92	27.50	46	0.51	0.0	4.6
9/5/2008	24.3	26.67	44	0.54	0.0	5.1
9/6/2008	22.88	25.83	49	0.45	0.0	4.3
9/7/2008	24.33	25.00	43	0.87	0.0	4.8
9/8/2008	22.64	28.61	47	0.76	0.0	4.8
9/9/2008	19.54	27.78	53	0.93	2.5	4.3
9/10/2008	19.43	28.06	56	0.67	0.0	4.3
9/11/2008	19.01	29.17	48	0.80	0.0	4.6
9/12/2008	19.47	29.44	44	0.60	0.0	4.8
9/13/2008	23.06	31.39	35	1.81	0.0	6.6
9/14/2008	16.02	28.89	39	2.27	0.0	5.6
9/15/2008	14.28	22.78	35	2.07	0.0	4.6
9/16/2008	18.66	21.67	24	0.64	0.0	3.6
9/17/2008	21.19	21.39	30	0.67	0.0	4.1
9/18/2008	14.42	22.22	46	0.38	0.0	2.8
9/19/2008	21.5	22.22	38	0.82	0.0	4.1
9/20/2008	22.07	22.78	35	1.14	0.0	4.6
9/21/2008	18.95	24.17	38	0.81	0.0	4.1
9/22/2008	21.24	25.28	40	0.58	0.0	4.8
9/23/2008	15.99	26.11	49	1.28	0.0	4.1
9/24/2008	16.75	27.22	39	1.61	0.0	4.8
9/25/2008	21.06	24.44	28	1.58	0.0	4.8
9/26/2008	19.78	22.50	31	0.55	0.0	3.6
9/27/2008	18.77	22.50	31	0.70	0.0	3.6
9/28/2008	21.12	22.50	25	0.88	0.0	3.8
9/29/2008	21.39	22.50	21	0.78	0.0	3.8
9/30/2008	21.07	22.78	22	0.47	0.0	3.8
10/1/2008	20.67	23.89	28	0.58	0.0	4.1
10/2/2008	20.33	23.33	31	0.69	0.0	4.1
10/3/2008	19.92	24.44	31	0.61	0.0	4.3
10/4/2008	19.14	23.33	38	1.12	0.0	4.3
10/5/2008	17.74	25.28	43	1.46	0.0	4.8
10/6/2008	9.87	25.83	51	0.30	0.0	2.8
10/7/2008	20.47	22.50	18	1.04	0.0	4.1
10/8/2008	21.26	20.00	18	0.88	0.0	3.3
10/9/2008	20.93	20.28	20	0.78	0.0	3.6
10/10/2008	18.76	22.78	32	0.80	0.0	4.1
10/11/2008	13.13	26.67	45	1.80	0.0	4.3
10/12/2008	9.23	25.00	57	2.22	0.0	3.6
10/13/2008	7.87	25.83	69	0.99	2.8	2.3
10/14/2008	16.71	26.67	38	0.82	0.0	4.1
10/15/2008	7.61	24.72	72	1.06	15.7	2.0
10/16/2008	13.13	20.83	51	1.07	0.0	2.8
10/17/2008	19.23	20.56	32	0.55	0.0	3.3
10/18/2008	19.35	19.72	30	0.90	0.0	3.3

10/19/2008	19.2	18.89	32	0.59	0.0	3.0
10/20/2008	18.25	20.83	38	0.78	0.0	3.0
10/21/2008	15.66	20.28	51	0.94	0.0	3.0
10/22/2008	15.95	24.44	38	0.41	0.0	3.6
10/23/2008	11.81	13.61	24	1.25	0.0	2.5
10/24/2008	18.65	15.00	25	0.57	0.0	2.5
10/25/2008	18	18.33	32	0.65	0.0	3.0
10/26/2008	13.11	23.33	41	0.30	0.0	2.5
10/27/2008	18.71	13.33	13	2.76	2.8	3.8

APPENDIX B

COLLEGE STATION CLIMATE DATA

Date	net Radiation (MJ/m^2 d)	avg air ^oC	avg rh %	avg wind m/sec	rain mm	RET mm
3/19/2007	12.62	20.83333	49	3.033166	0.0	3.8
3/20/2007	13.35	21.38889	44	2.771648	0.0	4.1
3/21/2007	9.66	21.66667	52	2.981757	0.0	3.3
3/22/2007	11.81	21.38889	50	2.384958	0.0	3.6
3/23/2007	10.31	21.94444	50	1.978152	0.0	3.3
3/24/2007	13.63	21.94444	51	3.346094	0.0	3.8
3/25/2007	8.80	21.66667	61	1.307592	0.0	2.5
3/26/2007	6.21	20	59	3.542792	51.8	2.3
3/27/2007	19.11	21.38889	52	1.522171	0.8	4.1
3/28/2007	15.46	22.22222	53	2.5146	0.0	4.1
3/29/2007	10.28	22.77778	59	2.208378	0.0	3.3
3/30/2007	6.06	22.5	57	2.617419	0.0	2.8
3/31/2007	20.32	19.16667	37	1.019251	2.3	3.8
4/1/2007	23.99	18.88889	22	0.603504	0.0	4.1
4/2/2007	14.77	21.66667	57	2.080971	0.0	3.6
4/3/2007	14.75	23.88889	56	1.361237	0.0	3.6
4/4/2007	10.94	18.05556	32	2.275434	0.0	3.3
4/5/2007	23.43	15.27778	30	0.987958	0.0	4.1
4/6/2007	22.10	15	32	1.090778	0.0	4.1
4/7/2007	2.61	5.277778	49	1.993798	12.2	1.3
4/8/2007	11.36	5	52	0.965606	1.3	1.5
4/9/2007	12.25	12.22222	51	0.695147	0.0	2.3
4/10/2007	19.40	18.61111	49	1.674165	0.5	3.8
4/11/2007	25.19	18.88889	20	1.502054	0.0	4.8
4/12/2007	24.50	17.77778	21	1.678635	0.0	5.1
4/13/2007	6.74	19.16667	52	2.633066	3.8	3.0
4/14/2007	8.33	10.55556	55	1.461821	0.3	2.0
4/15/2007	25.98	13.88889	26	1.969211	0.0	4.3
4/16/2007	22.06	13.61111	41	1.537818	0.0	3.8
4/17/2007	4.15	15.55556	70	1.455115	11.2	1.5
4/18/2007	12.10	15.55556	60	1.582522	0.0	2.5
4/19/2007	23.13	17.5	47	0.681736	0.0	4.1

4/20/2007	18.49	19.72222	44	1.093013	0.0	3.8
4/21/2007	21.28	18.88889	34	1.638402	0.0	4.8
4/22/2007	14.1	20.83333	53	2.28661	0.0	3.8
4/23/2007	10.99	21.66667	65	2.168144	0.0	3.0
4/24/2007	6.55	22.77778	67	3.574085	0.0	2.8
4/25/2007	19.95	21.11111	38	1.551229	19.1	4.3
4/26/2007	26.06	18.33333	35	0.663854	0.0	4.6
4/27/2007	19.77	18.88889	45	0.831494	0.0	3.8
4/28/2007	22.37	21.94444	44	0.431394	0.0	4.1
4/29/2007	20.49	23.05556	48	1.059485	0.0	4.3
4/30/2007	10.09	21.94444	44	1.56017	18.5	3.3
5/1/2007	1.83	20.86	90.2	0.447	15.5	0.4
5/2/2007	8.85	23.43	81.7	0.447	16.0	1.2
5/3/2007	7.10	21.3	86.8	0.447	3.8	0.8
5/4/2007	6.58	24.65	85.9	0.447	0.0	1.0
5/5/2007	10.62	25.8	80.2	0.447	0.0	1.5
5/6/2007	11.54	26.38	76.3	0.447	0.0	1.8
5/7/2007	13.73	26.45	72.3	0.447	0.0	2.1
5/8/2007	11.20	24.15	79.2	0.447	0.3	1.5
5/9/2007	12.85	23.81	72.9	0.447	0.0	1.8
5/10/2007	13.66	22.35	71.8	1.381	0.0	2.7
5/11/2007	15.21	22.16	71.3	2.223	0.0	3.4
5/12/2007	16.76	24.62	65.62	1.751	0.0	4.0
5/13/2007	10.55	25.28	68.21	1.486	2.0	3.3
5/14/2007	15.08	26.05	67.2	1.668	0.0	4.0
5/15/2007	16.25	25.91	63.97	1.731	0.0	4.4
5/16/2007	16.00	23.01	68.32	3.318	0.0	4.5
5/17/2007	16.82	21.21	57.8	2.613	0.0	4.8
5/18/2007	15.20	22.1	50.36	2.543	0.0	5.6
5/19/2007	16.57	21.96	50.39	2.337	0.0	5.4
5/20/2007	15.22	22.68	57.99	2.726	0.0	5.1
5/21/2007	9.94	23.13	71.3	3.576	0.0	4.0
5/22/2007	7.91	22.22	80	3.951	24.1	2.8
5/23/2007	13.73	25.33	75.3	3.786	0.0	4.2
5/24/2007	13.07	25.91	74.1	4.058	0.0	4.5
5/25/2007	7.07	22.24	86.2	2.926	12.5	1.8
5/26/2007	2.67	21.76	91.1	2.96	15.2	1.0
5/27/2007	6.67	21.89	86.9	3.022	3.8	1.7
5/28/2007	8.54	21.91	87	2.802	8.1	1.7
5/29/2007	11.65	24.23	78.1	2.09	0.0	2.8

5/30/2007	15.09	25.49	76.5	3.384	0.0	4.0
5/31/2007	16.13	25.46	74.8	2.772	0.0	3.9
6/1/2007	16.02	26.24	73.2	3.517	0.0	4.7
6/2/2007	14.34	26.38	72.8	1.943	0.0	3.7
6/3/2007	13.79	26.57	78.3	2.198	0.3	3.3
6/4/2007	15.02	24.69	76.2	1.59	1.0	2.9
6/5/2007	14.10	26.1	69.24	1.478	0.0	3.5
6/6/2007	16.24	25.9	73.7	3.73	0.0	4.6
6/7/2007	13.90	28.42	73.5	5.587	0.0	5.9
6/8/2007	14.20	29.4	74.6	3.421	0.0	5.0
6/9/2007	14.88	28.9	71.6	2.625	0.0	4.9
6/10/2007	15.28	28.08	71.4	2.187	0.0	4.4
6/11/2007	16.52	28.03	70.5	2.299	0.0	4.7
6/12/2007	17.90	28.02	68.69	1.771	0.0	4.5
6/13/2007	17.22	27.78	71.4	1.911	12.2	4.3
6/14/2007	14.31	25.27	80.4	2.382	3.6	3.0
6/15/2007	13.67	24.75	80.8	2.823	4.1	3.0
6/16/2007	7.66	24.51	85.8	2.665	0.5	2.0
6/17/2007	9.21	24.23	86.6	3.162	29.7	2.1
6/18/2007	15.74	27.9	75.9	4.097	0.0	4.9
6/19/2007	15.70	29.42	74.9	3.538	0.0	5.1
6/20/2007	7.77	26.4	79.4	2.357	0.0	2.8
6/21/2007	11.70	26.59	79.5	2.198	0.3	3.0
6/22/2007	7.74	25.93	82.2	1.752	10.4	2.2
6/23/2007	11.39	24.6	81.9	1.983	1.8	2.4
6/24/2007	12.89	25.29	77.5	2.948	0.5	3.5
6/25/2007	7.71	25.21	85	3.34	20.3	2.4
6/26/2007	11.42	27.13	82.3	3.852	2.3	3.4
6/27/2007	12.80	27.78	76.2	4.344	0.0	4.7
6/28/2007	13.06	26.12	80.4	3.579	25.2	3.5
6/29/2007	13.01	26.36	80.3	2.785	0.0	3.3
6/30/2007	14.71	26.81	81.1	2.526	0.0	3.2
7/1/2007	10.69	25.4	86.5	2.508	1.8	2.2
7/2/2007	9.51	25.05	84.6	2.992	1.8	2.4
7/3/2007	14.44	26.33	80.2	3.192	18.8	3.5
7/4/2007	7.02	24.74	84.7	2.623	2.5	2.1
7/5/2007	8.55	24.71	86.1	3.361	1.5	2.2
7/6/2007	14.81	26.2	83.1	2.367	5.3	2.8
7/7/2007	17.22	26.81	77.5	1.985	0.0	3.5
7/8/2007	13.29	26.68	80.1	2.678	4.3	3.3

7/9/2007	15.59	28.5	76.7	3.687	0.3	4.7
7/10/2007	15.68	28.77	74	3.403	0.0	5.1
7/11/2007	16.50	28.53	73.1	1.896	0.0	4.2
7/12/2007	15.61	28.71	74	2.391	0.3	4.4
7/13/2007	14.09	28.2	75.9	2.435	0.0	4.0
7/14/2007	7.85	26.21	84.3	2.287	12.7	2.2
7/15/2007	11.61	26.11	81.3	1.884	0.0	2.6
7/16/2007	16.83	26.41	77.6	2.065	0.0	3.5
7/17/2007	15.40	26.54	77.1	2.909	0.0	3.9
7/18/2007	13.03	26.25	76.2	2.879	0.0	3.8
7/19/2007	5.54	24.94	87	2.413	3.0	1.7
7/20/2007	5.34	24.89	89.3	2.115	29.2	1.4
7/21/2007	12.20	26.26	81.1	2.086	0.0	2.8
7/22/2007	14.19	27.56	76.1	1.546	0.0	3.2
7/23/2007	14.23	27.68	68.63	2.033	0.0	4.5
7/24/2007	15.25	26.07	65.16	2.118	0.0	4.6
7/25/2007	9.22	25.27	79.8	1.654	19.6	2.4
7/26/2007	8.64	24.57	88.5	2.223	13.2	1.7
7/27/2007	11.01	25.77	82.3	2.762	0.0	2.8
7/28/2007	13.67	27.29	76.9	1.566	0.0	3.1
7/29/2007	14.22	27.99	79.6	1.998	3.0	3.3
7/30/2007	16.06	28.6	76.1	2.115	0.0	4.0
7/31/2007	16.24	28.8	74.2	1.692	0.0	3.9
8/1/2007	14.40	27.77	76.6	2.192	0.0	3.7
8/2/2007	9.88	26.51	84.7	1.679	4.1	2.1
8/3/2007	12.89	28.11	75.5	2.195	0.0	3.8
8/4/2007	13.80	27.91	76.8	1.908	8.4	3.5
8/5/2007	14.06	28.36	76.1	2.696	0.0	4.2
8/6/2007	12.94	28.66	76.3	3.115	0.0	4.4
8/7/2007	13.42	28.57	74.6	3.027	0.0	4.6
8/8/2007	15.25	28.59	73.6	2.8	0.0	4.7
8/9/2007	14.99	28.4	73.3	1.767	0.0	3.9
8/10/2007	11.79	29.74	70.3	1.473	0.0	3.9
8/11/2007	13.55	30.69	66.7	1.429	0.0	4.5
8/12/2007	15.16	31.38	62.29	2.141	0.0	6.3
8/13/2007	13.94	31.59	55.82	1.941	0.0	6.8
8/14/2007	14.77	31.95	53.67	1.998	0.0	7.4
8/15/2007	11.59	30.56	63.35	2.291	0.0	5.9
8/16/2007	3.45	26.83	86.5	2.894	15.2	2.0
8/17/2007	7.57	27.01	86.4	2.64	8.4	2.2

8/18/2007	13.64	28.5	80	3.491	0.0	4.0
8/19/2007	14.16	28.44	75.6	3.435	0.0	4.7
8/20/2007	14.00	28.34	72.9	3.558	0.0	5.1
8/21/2007	13.96	28.57	73	3.015	0.0	4.8
8/22/2007	10.69	28.34	78.3	2.64	1.3	3.6
8/23/2007	13.54	29.27	74.7	3.26	0.0	4.9
8/24/2007	13.90	28.84	73.1	2.916	0.0	4.8
8/25/2007	12.76	28.22	74.9	1.991	3.8	3.7
8/26/2007	14.16	28.81	71.3	1.631	0.0	4.0
8/27/2007	10.84	27.36	75.3	1.864	0.0	3.3
8/28/2007	10.28	26.36	77.7	1.723	4.1	2.8
8/29/2007	11.52	26.62	80.6	1.722	3.8	2.6
8/30/2007	11.77	27.45	76.3	1.486	0.0	3.0
8/31/2007	11.93	26.94	75.9	2.261	0.8	3.5
9/1/2007	14.19	27.48	62.3	2.558	0.0	5.7
9/2/2007	8.94	26.52	74	2.253	0.0	3.5
9/3/2007	7.20	25.58	83.8	1.713	11.7	1.9
9/4/2007	5.98	24.71	86.1	1.531	2.5	1.5
9/5/2007	9.08	27.32	82.3	3.397	1.3	3.1
9/6/2007	11.34	28.19	76.6	3.54	0.0	4.3
9/7/2007	11.75	28.64	76.3	2.836	0.0	4.1
9/8/2007	11.46	28.39	78.9	2.067	2.0	3.3
9/9/2007	12.46	28.1	76.8	1.546	13.7	3.1
9/10/2007	12.83	28.64	70.8	1.475	0.5	3.7
9/11/2007	3.94	25.02	82.3	3.016	0.0	2.4
9/12/2007	7.23	24.55	75.3	3.138	0.0	3.4
9/13/2007	9.30	25.64	76.1	1.719	0.5	2.8
9/14/2007	10.90	27.46	67.79	1.69	0.0	3.9
9/15/2007	11.68	27.69	67.54	2.425	0.0	4.8
9/16/2007	12.84	26.43	63.48	1.808	0.0	4.4
9/17/2007	12.77	26.77	59.47	2.406	0.0	5.6
9/18/2007	11.31	27.2	65.94	2.606	0.0	5.0
9/19/2007	8.05	26.49	80.2	1.657	13.2	2.4
9/20/2007	11.38	26.8	63.72	1.822	0.0	4.4
9/21/2007	11.49	25.93	62.61	1.273	0.0	3.6
9/22/2007	11.71	26.56	58.79	1.638	0.0	4.6
9/23/2007	9.02	26.3	63.63	1.976	0.0	4.3
9/24/2007	10.60	26.52	69.48	1.856	0.0	3.7
9/25/2007	11.21	27.53	70.9	1.883	0.0	3.8
9/26/2007	10.11	27.75	71	1.811	0.0	3.7

9/27/2007	8.93	26.25	78	1.709	3.3	2.6
9/28/2007	10.23	26.51	65.28	2.537	0.0	4.8
9/29/2007	9.97	25.83	66.95	2.992	0.0	4.8
9/30/2007	7.89	26.39	78.9	3.017	0.0	3.2
10/1/2007	6.18	26.93	79.6	1.881	11.7	2.5
10/2/2007	10.36	26.31	73.4	2.364	5.6	3.7
10/3/2007	10.86	25.2	63.36	1.395	0.0	3.5
10/4/2007	10.79	26.33	60.23	1.483	0.0	4.1
10/5/2007	8.59	26.92	71.8	2.367	0.0	3.9
10/6/2007	7.17	27.11	76.9	2.474	3.6	3.3
10/7/2007	5.12	26.8	79.9	2.575	0.0	2.8
10/8/2007	6.84	26.75	78.1	1.925	0.0	2.7
10/9/2007	7.72	26.24	76.2	2.644	0.5	3.4
10/10/2007	10.34	24.96	59.97	2.273	0.0	4.8
10/11/2007	10.28	24.08	49.86	1.615	0.0	4.7
10/12/2007	10.10	23.15	54.36	1.871	0.0	4.4
10/13/2007	10.13	23.33	59.69	3.675	0.0	5.6
10/14/2007	7.51	23.43	72.7	4.198	20.3	4.0
10/15/2007	3.44	21.69	90.3	3.442	36.3	1.2
10/16/2007	2.76	21.45	87.9	2.174	0.0	1.2
10/17/2007	7.91	25.88	78.8	3.265	0.0	3.3
10/18/2007	8.02	26.51	61.2	2.767	0.0	5.4
10/19/2007	9.97	21.83	40.09	1.417	0.0	4.5
10/20/2007	9.63	22	58.24	3.045	0.0	4.9
10/21/2007	8.85	23.47	68.04	4.13	0.0	4.7
10/22/2007	1.92	15.24	82.7	4.615	9.9	1.6
10/23/2007	9.49	13.78	54.07	3.703	0.0	3.7
10/24/2007	9.20	15.62	51.11	3.438	0.0	4.2
10/25/2007	9.36	13.46	50.99	2.497	0.0	3.3
10/26/2007	9.22	14.48	52.31	1.256	0.0	2.3
10/27/2007	8.91	15.63	56.03	2.467	0.0	3.3
10/28/2007	8.66	16.68	63.56	2.489	0.0	3.0
10/29/2007	8.57	16.48	58.29	2.309	0.0	3.2
10/30/2007	8.44	17.28	60.12	1.823	0.0	2.8
10/31/2007	7.97	19.15	71.2	1.682	0.0	2.2
11/1/2007	7.84	18.2	74	1.785	0.0	2.0
11/2/2007	7.48	19.06	72.7	1.4	0.0	1.9
11/3/2007	7.29	19.89	69.61	1.829	0.0	2.5
11/4/2007	7.51	20.36	67.06	1.56	0.0	2.5
11/5/2007	7.61	21.2	74.9	2.914	0.0	2.9

11/6/2007	3.32	17.43	55.28	2.998	2.5	3.8
11/7/2007	5.79	14.88	37.9	2.331	0.0	4.1
11/8/2007	4.92	18	66.81	3.325	0.0	3.2
11/9/2007	5.97	22.19	75.1	2.511	0.0	2.7
11/10/2007	5.26	21.8	82	3.16	0.0	2.2
11/11/2007	5.97	22.11	71.8	3.862	0.0	3.7
11/12/2007	4.91	22.76	73.6	2.96	0.0	3.1
11/13/2007	5.39	22.17	78	2.09	0.0	2.2
11/14/2007	6.83	22.92	64.27	4.069	0.0	4.9
11/15/2007	7.49	13.88	24.86	4.002	0.0	6.1
11/16/2007	6.92	13.76	43.73	2.873	0.0	3.9
11/17/2007	2.27	17.81	84.5	1.756	26.9	1.1
11/18/2007	5.21	19.27	85	2.045	20.1	1.3
11/19/2007	5.82	20.83	82.9	2.01	0.0	1.6
11/20/2007	3.25	21.23	88.3	3.207	13.7	1.4
11/21/2007	3.79	19.42	75.5	4.67	0.0	2.9
11/22/2007	4.79	7.53	59.99	4.586	0.0	2.4
11/23/2007	2.82	7.44	68.37	2.943	0.3	1.5
11/24/2007	0.54	5.681	90.8	4.218	30.0	0.5
11/25/2007	0.80	5.566	94.2	2.876	3.8	0.3
11/26/2007	6.86	7.75	75.1	1.969	0.0	1.1
11/27/2007	6.78	9.87	74.2	1.57	0.0	1.2
11/28/2007	5.77	12.84	79.5	2.036	0.0	1.3
11/29/2007	6.26	13.51	74.2	1.631	0.0	1.4
11/30/2007	3.54	16.26	85.9	2.568	0.0	1.1
12/1/2007	2.05	20.07	80.2	5.031	0.0	2.5
3/1/2008	8.81	20.04	74.6	2.952	0.0	2.8
3/2/2008	3.56	20.13	81.1	5.822	0.0	2.6
3/3/2008	1.66	11.59	84	6.228	14.7	1.3
3/4/2008	11.37	8.91	54.18	3.056	0.0	2.6
3/5/2008	11.15	14.43	61.14	3.951	0.0	3.4
3/6/2008	1.74	9.36	85.8	3.932	11.2	0.9
3/7/2008	10.45	6.36	65.09	4.564	1.3	2.0
3/8/2008	11.78	8.39	45.74	2.688	0.0	2.8
3/9/2008	6.94	14.85	70	4.273	0.0	2.8
3/10/2008	1.27	13.12	91.4	2.278	37.1	0.5
3/11/2008	11.17	13.79	71.8	2.188	0.0	2.0
3/12/2008	12.22	15.56	63.73	2.871	0.0	3.1
3/13/2008	6.19	18	83.7	4.674	0.0	1.9

3/14/2008	11.49	23.61	69.99	4.293	0.0	4.6
3/15/2008	12.53	20.43	58.11	3.439	0.0	4.9
3/16/2008	9.86	18.67	67.12	4.985	0.0	4.0
3/17/2008	4.75	23.36	77.4	6.415	0.0	3.8
3/18/2008	1.03	20.62	86.7	6.03	30.2	1.8
3/19/2008	12.82	13.95	56.94	4.587	0.0	3.9
3/20/2008	13.17	14.89	45.72	2.311	0.0	3.9
3/21/2008	11.38	15.73	69.39	2.989	0.0	2.7
3/22/2008	12.65	18.59	63.3	1.552	0.0	2.8
3/23/2008	10.90	16.05	40.62	4.305	0.0	5.8
3/24/2008	13.42	12.74	42.54	2.674	0.0	3.9
3/25/2008	9.04	16.4	67.33	5.122	0.0	3.5
3/26/2008	6.18	19.49	80.2	5.253	0.0	2.6
3/27/2008	11.10	21.63	71.5	5.469	0.0	4.3
3/28/2008	6.02	20.64	82.3	3.385	0.0	2.1
3/29/2008	7.30	19.04	85.3	3.016	1.5	1.6
3/30/2008	6.86	23.63	83.5	4.608	0.8	2.6
3/31/2008	5.77	23.74	80.4	5.536	0.0	3.3
4/1/2008	11.25	22.34	77.9	3.244	0.0	3.0
4/2/2008	7.89	20.95	81.3	2.925	0.0	2.2
4/3/2008	5.00	23.51	79.4	5.167	0.0	3.3
4/4/2008	3.27	17.51	86	3.825	23.1	1.4
4/5/2008	14.92	15.15	65.27	2.169	0.0	2.7
4/6/2008	11.90	18.06	76.7	2.815	0.0	2.4
4/7/2008	10.49	21.64	78.7	3.426	0.0	2.8
4/8/2008	10.21	24.22	75.8	4.069	0.0	3.8
4/9/2008	3.77	22.55	85.6	4.568	0.0	2.1
4/10/2008	10.10	23.5	63.91	3.509	0.0	5.0
4/11/2008	15.05	20.68	50.43	3.4	0.0	5.9
4/12/2008	15.42	16.57	44.5	3.431	0.0	5.2
4/13/2008	15.59	14.66	49.01	3.243	0.0	4.3
4/14/2008	16.05	13.83	40.26	2.426	0.0	4.2
4/15/2008	15.63	16.39	48.52	4.202	0.0	5.2
4/16/2008	12.46	18.4	66.74	5.344	0.0	4.2
4/17/2008	10.62	21.74	70.8	5.976	0.0	4.6
4/18/2008	15.72	16.21	64.87	3.411	34.3	3.4
4/19/2008	16.23	19.1	54.49	2.675	0.0	4.6
4/20/2008	9.58	20.23	76.2	3.859	0.0	3.0
4/21/2008	11.55	24.31	78.3	3.377	0.0	3.3
4/22/2008	9.58	25.26	79.8	2.831	0.0	3.0

4/23/2008	13.35	25.22	72.4	4.342	0.0	4.8
4/24/2008	9.99	24.58	75.4	4.99	0.0	4.2
4/25/2008	7.85	24.36	78.2	4.053	0.3	3.4
4/26/2008	13.20	22.12	73.8	2.154	1.0	3.0
4/27/2008	7.31	17.72	75.4	3.988	0.5	2.6
4/28/2008	17.01	16.42	53.95	1.952	0.0	3.5
4/29/2008	17.23	18.71	49.55	2.751	0.0	5.0
4/30/2008	16.05	20.92	64.33	5.281	0.0	5.2
5/1/2008	7.94	23.31	78	5.129	0.0	3.5
5/2/2008	12.91	25.49	66.42	3.912	0.0	5.5
5/3/2008	16.97	19.42	51.92	3.737	0.0	5.6
5/4/2008	16.19	20.68	57.12	2.673	0.0	4.7
5/5/2008	1.77	19.57	90.6	2.69	33.3	0.9
5/6/2008	5.52	21.11	89.3	3.712	0.0	1.4
5/7/2008	5.11	23.68	82.2	5.552	0.3	3.0
5/8/2008	17.02	23.89	66.68	2.156	0.0	4.2
5/9/2008	15.23	26.09	75.9	3.125	0.0	4.0
5/10/2008	7.30	26.25	81.6	3.118	0.0	2.9
5/11/2008	16.27	22.3	47.03	3.801	0.0	7.1
5/12/2008	7.55	19.98	56.82	3.379	0.0	4.7
5/13/2008	3.18	24.86	83.1	3.649	0.0	2.5
5/14/2008	9.73	25.18	83.3	2.809	11.4	2.5
5/15/2008	4.57	20.24	88.4	2.534	44.5	1.2
5/16/2008	14.97	20.19	64.81	3.185	0.0	4.1
5/17/2008	13.07	20.17	65.15	1.786	0.0	3.1
5/18/2008	17.83	23.44	59.22	1.858	0.0	4.5
5/19/2008	18.22	25.76	56.81	2.24	0.0	5.8
5/20/2008	17.82	27.3	64.16	2.86	0.0	5.9
5/21/2008	14.81	27.04	73.7	3.906	0.0	4.9
5/22/2008	11.71	27.5	75.5	5.615	0.0	5.2
5/23/2008	15.34	29.18	71	5.198	0.0	6.5
5/24/2008	12.12	28.53	75.6	3.889	0.0	4.8
5/25/2008	15.01	28.61	73.4	3.798	0.0	5.3
5/26/2008	10.73	27.89	73.9	4.149	0.0	5.0
5/27/2008	13.56	26.46	74.7	4.172	0.3	4.6
5/28/2008	17.08	26.72	67.66	1.971	0.0	4.5
5/29/2008	15.71	26.98	68.04	2.641	0.0	5.0
5/30/2008	17.87	26.44	63.61	3.28	0.0	6.0
5/31/2008	17.06	27.56	68.79	3.631	0.0	5.8
6/1/2008	16.74	28.04	68.57	3.763	0.0	6.0

6/2/2008	17.93	28.54	68.57	4.09	0.0	6.4
6/3/2008	17.11	28.61	68.33	5.109	0.0	6.9
6/4/2008	13.87	28.49	69.37	6.217	0.0	6.9
6/5/2008	14.19	29.13	67.02	7.67	0.0	8.2
6/6/2008	15.26	29.2	70.5	5.481	0.3	6.7
6/7/2008	14.65	29.11	70.9	5.319	0.0	6.5
6/8/2008	16.98	29.41	67.67	5.191	0.0	7.3
6/9/2008	15.71	29.31	65.53	5.095	0.0	7.6
6/10/2008	17.27	27.62	70.4	3.624	0.0	5.5
6/11/2008	16.62	28.67	66.9	4.678	0.0	7.0
6/12/2008	15.65	28.64	67.7	4.751	0.0	6.8
6/13/2008	17.19	28.72	70.2	4.136	0.0	6.2
6/14/2008	15.17	29.14	66.97	2.863	0.0	5.8
6/15/2008	18.14	29.52	64.53	2.852	0.0	6.5
6/16/2008	17.33	29.68	64.03	2.959	0.0	6.7
6/17/2008	15.89	28.59	66.04	2.528	0.0	5.6
6/18/2008	16.01	29.45	60.24	2.226	0.0	6.2
6/19/2008	12.47	28.66	64.1	2.807	0.0	5.9
6/20/2008	12.87	27.8	61.81	2.09	0.0	5.2
6/21/2008	15.84	28.62	58.34	2.154	0.0	6.1
6/22/2008	18.63	29.25	48.5	2.172	0.0	7.8
6/23/2008	17.38	29.41	50.4	2.356	0.0	7.8
6/24/2008	14.15	27.98	67.94	3.531	0.0	5.8
6/25/2008	15.28	28.9	66.08	3.925	0.0	6.7
6/26/2008	16.31	28.11	70.9	4.411	0.0	5.9
6/27/2008	16.27	29.28	66.9	4.349	0.0	7.0
6/28/2008	16.34	29.21	66.52	4.338	0.0	7.0
6/29/2008	13.85	27.87	67.65	2.41	0.0	4.9
6/30/2008	14.33	27.46	63.43	2.132	9.1	5.1
7/1/2008	18.17	28.04	49.23	2.425	0.0	7.6
7/2/2008	15.72	28.24	65.54	2.478	0.0	5.5
7/3/2008	15.90	28.15	62.35	2.472	0.0	5.9
7/4/2008	16.41	27.18	68.92	2.87	0.0	5.1
7/5/2008	15.84	26.95	68.92	3.032	0.0	5.2
7/6/2008	15.13	27.74	66.6	2.952	0.0	5.6
7/7/2008	15.55	28.95	64.9	3.324	0.0	6.5
7/8/2008	13.56	27.88	72.7	2.639	7.1	4.5
7/9/2008	15.28	27.89	73.3	2.014	25.4	4.0
7/10/2008	15.07	28.23	70.8	2.807	3.0	5.0
7/11/2008	16.56	29.05	66.02	3.692	0.0	6.7

7/12/2008	18.17	29.24	64.86	3.856	0.0	7.1
7/13/2008	15.97	29.07	63.63	2.606	0.0	6.1
7/14/2008	10.52	27.7	73.6	2.497	2.5	4.0
7/15/2008	13.33	27.96	73.3	2.264	0.0	4.1
7/16/2008	11.96	28.94	68.02	1.683	0.5	4.2
7/17/2008	17.04	29.29	62	2.418	0.0	6.3
7/18/2008	16.45	28.7	63.87	2.708	0.0	6.1
7/19/2008	15.70	28.94	61.4	2.649	0.0	6.4
7/20/2008	17.01	29.66	59.89	2.226	0.0	6.4
7/21/2008	17.08	30.78	55.54	2.35	0.0	7.5
7/22/2008	15.53	30.03	58.82	2.719	0.0	7.2
7/23/2008	14.18	28.34	71.2	3.565	3.6	5.4
7/24/2008	12.01	26.88	79.9	3.445	0.0	3.6
7/25/2008	15.57	29.39	68.35	3.562	0.0	6.2
7/26/2008	16.63	30.11	61.94	2.737	0.0	6.8
7/27/2008	17.28	29.91	54.5	2.633	0.0	7.8
7/28/2008	17.43	29.78	60.73	3.399	0.0	7.6
7/29/2008	16.39	29.37	64.31	3.669	0.0	7.0
7/30/2008	15.53	29.53	64.85	3.38	0.0	6.7
7/31/2008	14.62	30.6	63.61	3.975	0.0	7.7
8/1/2008	13.58	30.55	63.33	3.169	0.0	7.0
8/2/2008	16.92	31.3	58.44	2.59	0.0	7.6
8/3/2008	13.78	29.19	64.19	2.449	0.3	5.7
8/4/2008	15.97	30.32	58.06	1.968	0.0	6.4
8/5/2008	3.83	26.15	80.3	2.745	17.8	2.7
8/6/2008	14.37	27.94	75.6	3.587	34.0	4.6
8/7/2008	15.25	29.59	67.7	2.334	0.0	5.4
8/8/2008	15.33	29.87	65.51	2.087	0.0	5.4
8/9/2008	15.08	29.86	64.95	3.192	0.0	6.6
8/10/2008	13.82	29.8	66.82	4.252	0.0	7.0
8/11/2008	11.54	29.71	67.29	3.82	0.0	6.5
8/12/2008	4.55	27.11	83.4	2.301	36.8	2.2
8/13/2008	14.24	29.37	68.32	2.075	0.0	4.9
8/14/2008	16.05	29.66	64.24	1.747	0.0	5.2
8/15/2008	12.05	27.32	78.8	2.066	5.8	3.2
8/16/2008	12.41	27.18	79.1	2.189	0.0	3.2
8/17/2008	12.15	26.46	72.5	2.457	0.0	4.0
8/18/2008	9.17	25.28	67	0.72	6.6	2.3
8/19/2008	6.83	23.89	76	0.85	28.7	2.0
8/20/2008	16.71	26.39	47	0.45	0.3	3.8

8/21/2008	14.3	26.67	58	1.46	3.3	3.6
8/22/2008	15.59	28.06	53	0.94	0.5	3.8
8/23/2008	16	27.50	51	0.75	0.0	3.6
8/24/2008	20.92	26.94	47	0.64	0.0	4.6
8/25/2008	20.92	28.33	40	0.75	0.0	4.6
8/26/2008	20.61	28.33	36	0.46	0.0	4.6
8/27/2008	20.75	29.17	41	1.04	0.0	5.1
8/28/2008	19.82	28.61	38	0.83	0.0	4.6
8/29/2008	20.36	28.33	39	0.64	0.0	4.6
8/30/2008	19.99	28.61	36	0.67	0.0	4.3
8/31/2008	19.75	28.61	38	0.96	0.0	4.8
9/1/2008	12.75	28.97	63.54	3.59	0.0	6.8
9/2/2008	11.32	29.27	63.03	3.468	0.0	6.8
9/3/2008	9.21	26.74	64.78	3.146	0.0	5.4
9/4/2008	13.80	25.53	64.2	2.62	0.0	5.0
9/5/2008	14.36	26.72	60.88	2.431	0.0	5.5
9/6/2008	14.34	25.95	61.15	2.327	0.0	5.2
9/7/2008	13.03	26.34	61.21	2.327	0.0	5.2
9/8/2008	10.50	26.89	70.8	2.294	2.3	4.0
9/9/2008	11.17	27.62	74.3	2.181	1.0	3.7
9/10/2008	11.15	28.85	65.41	2.349	0.0	5.2
9/11/2008	11.29	29.25	64.29	2.693	2.8	5.8
9/12/2008	8.10	28.15	69.96	4.048	0.0	5.5
9/13/2008	1.16	25.46	90.3	5.258	74.2	1.7
9/14/2008	8.55	25.74	74.6	2.72	3.8	3.6
9/15/2008	7.48	20.58	61.42	3.451	0.0	4.4
9/16/2008	11.21	19.96	60.88	2.072	0.0	3.5
9/17/2008	9.11	20.24	68.45	1.69	0.0	2.6
9/18/2008	7.61	21.23	70.3	2.171	0.0	2.9
9/19/2008	11.56	22.71	67.46	1.787	0.0	3.3
9/20/2008	11.75	24.46	67.26	1.99	0.0	3.8
9/21/2008	11.29	25.31	66.45	2.359	0.0	4.3
9/22/2008	10.46	25.4	70.4	2.603	0.0	4.0
9/23/2008	9.77	25.99	67.93	2.449	0.0	4.3
9/24/2008	9.04	24.81	73.4	2.355	0.0	3.3
9/25/2008	11.80	23.87	64.4	2.239	0.0	4.2
9/26/2008	11.67	23.78	58.85	1.719	0.0	4.1
9/27/2008	11.92	23.96	53.61	1.708	0.0	4.6
9/28/2008	11.74	23.84	53.43	1.9	0.0	4.8
9/29/2008	11.75	23.68	53.65	1.987	0.0	4.9

9/30/2008	11.02	23.54	57.1	2.512	0.0	5.0
10/1/2008	11.35	22.23	46.48	2.232	0.0	5.4
10/2/2008	11.51	22.93	48.48	1.805	0.0	4.9
10/3/2008	10.63	23.82	61.37	2.898	0.0	5.0
10/4/2008	10.36	23.84	66.66	3.395	0.0	4.6
10/5/2008	9.30	23.61	66.37	3.806	0.0	4.8
10/6/2008	6.77	25.21	75.8	3.431	0.0	3.6
10/7/2008	9.99	22.66	64.26	3.024	26.2	4.4
10/8/2008	11.08	19.84	50.94	2.032	0.0	4.2
10/9/2008	10.88	21.23	54.03	1.936	0.0	4.2
10/10/2008	10.10	21.79	70.3	2.778	0.0	3.5
10/11/2008	9.34	23.29	72.4	2.788	0.0	3.5
10/12/2008	7.46	23.73	75.6	3.133	0.0	3.3
10/13/2008	6.83	24.87	75.4	2.749	0.0	3.2
10/14/2008	5.61	24.52	82.4	2.809	1.3	2.3
10/15/2008	4.73	23.62	89.6	2.389	15.5	1.3
10/16/2008	2.93	17.73	84.7	3.624	0.0	1.5
10/17/2008	5.90	19.18	78.2	2.374	0.0	2.0
10/18/2008	9.68	19.64	63.93	1.828	0.0	3.0
10/19/2008	9.55	19.49	62.63	2.513	0.0	3.6
10/20/2008	9.39	20.41	67.36	2.204	0.0	3.1
10/21/2008	9.24	21.15	69.38	2.015	0.0	2.9
10/22/2008	6.61	20.32	73.8	3.509	0.0	3.0
10/23/2008	8.39	15.24	46.66	2.755	0.0	4.0
10/24/2008	9.45	16.28	49.72	1.647	0.0	3.1
10/25/2008	9.06	18.99	55.09	1.752	0.0	3.4
10/26/2008	8.77	21.05	65.32	1.79	0.0	3.0
10/27/2008	9.30	14.85	28.72	4.381	0.0	6.4
10/28/2008	9.04	11.6	38.71	1.518	0.0	2.7
10/29/2008	8.91	15.08	43.77	2.313	0.0	3.9
10/30/2008	8.45	18.46	67.84	3.4	0.0	3.3
10/31/2008	7.31	20.17	70.7	2.941	0.0	3.1
11/1/2008	13.83	21.39	40	0.55	0.0	2.5
11/2/2008	14.12	20.00	38	1.17	0.0	2.8
11/3/2008	14.47	18.33	30	1.11	0.0	3.0
11/4/2008	12.36	18.89	52	1.40	0.0	2.8
11/5/2008	10.86	22.78	44	2.96	0.0	3.8
11/6/2008	10.84	19.17	24	1.61	4.6	2.5
11/7/2008	14.73	15.28	17	0.69	0.0	2.5
11/8/2008	14.51	16.39	13	0.46	0.0	2.5

11/9/2008	14.14	15.28	23	1.41	0.0	2.8
11/10/2008	2.85	18.33	73	2.30	9.4	1.5
11/11/2008	7.54	20.00	62	1.70	15.7	2.0
11/12/2008	4.25	16.11	71	0.65	0.0	1.0
11/13/2008	9.1	16.39	65	0.61	0.0	1.5
11/14/2008	9.45	19.72	41	1.07	0.0	2.3
11/15/2008	14.12	10.56	27	1.70	0.0	2.5
11/16/2008	13.85	9.72	22	0.66	0.0	1.8
11/17/2008	13.61	14.72	17	1.30	0.0	2.5
11/18/2008	13.16	12.50	33	1.26	0.0	2.0
11/19/2008	13.07	14.17	32	0.80	0.0	2.3
11/20/2008	11.61	16.94	35	0.66	0.0	2.3
11/21/2008	12.8	8.06	26	1.81	0.0	2.3
11/22/2008	7.27	11.67	48	0.82	0.0	1.5
11/23/2008	5.52	18.06	56	0.76	1.8	1.8
11/24/2008	10.44	14.72	26	1.34	0.0	2.3
11/25/2008	13.31	11.39	18	0.25	0.0	1.3
11/26/2008	7.45	14.44	44	1.38	0.0	1.8
11/27/2008	5.48	20.00	63	0.63	0.0	1.3
11/28/2008	5.71	18.89	66	1.93	0.0	1.5
11/29/2008	3.37	11.94	64	1.02	0.0	1.0
11/30/2008	9.3	11.39	27	3.27	0.0	3.0
12/1/2008	12.59	7.78	22	2.29	0.0	2.5

APPENDIX C

SAN ANTONIO WATER USE DATA

year	season	plant treatment	BLOCK	day of year	actual H_2O (mm) use/drydown	avg RET (mm) day/drydown	K_L
2007	early-	tree	1	84	0.522	2.5	0.21
2007	early-	St.A	1	84	0.336	2.5	0.13
2007	early-	St.A/tree	1	84	0.456	2.5	0.18
2007	early-	native	1	84	0.184	2.5	0.07
2007	early-	Nat/tree	1	84	1.022	2.5	0.41
2007	early-	St.A	2	84	0.43	2.5	0.17
2007	early-	Nat/tree	2	84	1.512	2.5	0.60
2007	early-	tree	2	84	0.718	2.5	0.29
2007	early-	native	2	84	0.39	2.5	0.16
2007	early-	St.A/tree	2	84	1.078	2.5	0.43
2007	early-	Nat/tree	3	84	1.356	2.5	0.54
2007	early-	native	3	84	1.238	2.5	0.50
2007	early-	tree	3	84	0.926	2.5	0.37
2007	early-	St.A	3	84	0.748	2.5	0.30
2007	early-	St.A/tree	3	84	0.54	2.5	0.22
2007	early-	tree	1	88	0.7	2.8	0.25
2007	early-	St.A	1	88	1.325	2.8	0.47
2007	early-	St.A/tree	1	88	3.9	2.8	1.39
2007	early-	native	1	88	3.273	2.8	1.17
2007	early-	Nat/tree	1	88	1.605	2.8	0.57
2007	early-	St.A	2	88	1.13	2.8	0.40
2007	early-	Nat/tree	2	88	1.745	2.8	0.62
2007	early-	tree	2	88	0.54	2.8	0.19
2007	early-	native	2	88	0.349	2.8	0.12
2007	early-	St.A/tree	2	88	2.935	2.8	1.05
2007	early-	Nat/tree	3	88	1.73	2.8	0.62
2007	early-	native	3	88	1.685	2.8	0.60
2007	early-	tree	3	88	4.78	2.8	1.71
2007	early-	St.A	3	88	0.515	2.8	0.18
2007	early-	St.A/tree	3	88	1.5	2.8	0.54
2007	early-	tree	1	109	0.00	4.3	0.00
2007	early-	St.A	1	109	0.17	4.3	0.04
2007	early-	St.A/tree	1	109	1.58	4.3	0.37
2007	early-	native	1	109	0.69	4.3	0.16
2007	early-	Nat/tree	1	109	1.65	4.3	0.38
2007	early-	St.A	2	109	0.82	4.3	0.19
2007	early-	Nat/tree	2	109	0.96	4.3	0.22
2007	early-	tree	2	109	0.07	4.3	0.02
2007	early-	native	2	109	1.01	4.3	0.23

2007	early-	St.A/tree	2	109	0.48	4.3	0.11
2007	early-	Nat/tree	3	109	1.89	4.3	0.44
2007	early-	native	3	109	1.67	4.3	0.39
2007	early-	tree	3	109	0.00	4.3	0.00
2007	early-	St.A	3	109	1.44	4.3	0.33
2007	early-	St.A/tree	3	109	0.30	4.3	0.07
2007	early-	tree	1	117	1.05	3.9	0.27
2007	early-	St.A	1	117	0.51	3.9	0.13
2007	early-	St.A/tree	1	117	3.08	3.9	0.79
2007	early-	native	1	117	1.31	3.9	0.33
2007	early-	Nat/tree	1	117	3.27	3.9	0.84
2007	early-	St.A	2	117	1.74	3.9	0.45
2007	early-	Nat/tree	2	117	3.23	3.9	0.83
2007	early-	tree	2	117	1.10	3.9	0.28
2007	early-	native	2	117	3.26	3.9	0.84
2007	early-	St.A/tree	2	117	1.98	3.9	0.51
2007	early-	Nat/tree	3	117	3.63	3.9	0.93
2007	early-	native	3	117	3.27	3.9	0.84
2007	early-	tree	3	117	1.64	3.9	0.42
2007	early-	St.A	3	117	2.49	3.9	0.64
2007	early-	St.A/tree	3	117	1.73	3.9	0.44
2007	early-	tree	1	124	1.68	3.3	0.51
2007	early-	St.A	1	124	0.44	3.3	0.13
2007	early-	St.A/tree	1	124	1.13	3.3	0.34
2007	early-	native	1	124	0.61	3.3	0.19
2007	early-	Nat/tree	1	124	1.43	3.3	0.43
2007	early-	St.A	2	124	1.50	3.3	0.45
2007	early-	Nat/tree	2	124	0.96	3.3	0.29
2007	early-	tree	2	124	0.18	3.3	0.05
2007	early-	native	2	124	1.43	3.3	0.43
2007	early-	St.A/tree	2	124	1.72	3.3	0.52
2007	early-	Nat/tree	3	124	1.65	3.3	0.50
2007	early-	native	3	124	2.55	3.3	0.77
2007	early-	tree	3	124	1.14	3.3	0.34
2007	early-	St.A	3	124	1.95	3.3	0.59
2007	early-	St.A/tree	3	124	1.22	3.3	0.37
2007	early-	tree	1	149	0.98	4.6	0.21
2007	early-	St.A	1	149	3.83	4.6	0.83
2007	early-	St.A/tree	1	149	2.50	4.6	0.54
2007	early-	native	1	149	0.79	4.6	0.17
2007	early-	Nat/tree	1	149	2.01	4.6	0.44
2007	early-	St.A	2	149	2.26	4.6	0.49
2007	early-	Nat/tree	2	149	2.53	4.6	0.55
2007	early-	tree	2	149	-0.21	4.6	0.00
2007	early-	native	2	149	2.29	4.6	0.50
2007	early-	St.A/tree	2	149	0.74	4.6	0.16
2007	early-	Nat/tree	3	149	3.41	4.6	0.74
2007	early-	native	3	149	3.54	4.6	0.77

2007	early-	tree	3	149	1.41	4.6	0.31
2007	early-	St.A	3	149	3.03	4.6	0.66
2007	early-	St.A/tree	3	149	2.89	4.6	0.63
2007	mid-	tree	1	166	1.28	5.3	0.24
2007	mid-	St.A	1	166	4.23	5.3	0.80
2007	mid-	St.A/tree	1	166	0.82	5.3	0.15
2007	mid-	native	1	166	1.21	5.3	0.23
2007	mid-	Nat/tree	1	166	2.87	5.3	0.54
2007	mid-	St.A	2	166	2.74	5.3	0.52
2007	mid-	Nat/tree	2	166	1.96	5.3	0.37
2007	mid-	tree	2	166	0.55	5.3	0.10
2007	mid-	native	2	166	2.10	5.3	0.40
2007	mid-	St.A/tree	2	166	2.78	5.3	0.53
2007	mid-	Nat/tree	3	166	1.67	5.3	0.31
2007	mid-	native	3	166	1.73	5.3	0.33
2007	mid-	tree	3	166	4.11	5.3	0.78
2007	mid-	St.A	3	166	2.65	5.3	0.50
2007	mid-	St.A/tree	3	166	1.67	5.3	0.32
2007	mid-	tree	1	194	0.26	5.5	0.05
2007	mid-	St.A	1	194	0.67	5.5	0.12
2007	mid-	St.A/tree	1	194	0.59	5.5	0.11
2007	mid-	native	1	194	0.94	5.5	0.17
2007	mid-	Nat/tree	1	194	1.57	5.5	0.29
2007	mid-	St.A	2	194	0.97	5.5	0.18
2007	mid-	Nat/tree	2	194	1.36	5.5	0.25
2007	mid-	tree	2	194	3.74	5.5	0.68
2007	mid-	native	2	194	2.19	5.5	0.40
2007	mid-	St.A/tree	2	194	0.82	5.5	0.15
2007	mid-	Nat/tree	3	194	3.77	5.5	0.69
2007	mid-	native	3	194	0.59	5.5	0.11
2007	mid-	tree	3	194	1.31	5.5	0.24
2007	mid-	St.A	3	194	0.81	5.5	0.15
2007	mid-	St.A/tree	3	194	2.81	5.5	0.51
2007	mid-	tree	1	212	2.84	3.9	0.73
2007	mid-	St.A	1	212	2.71	3.9	0.69
2007	mid-	St.A/tree	1	212	1.75	3.9	0.45
2007	mid-	native	1	212	1.34	3.9	0.34
2007	mid-	Nat/tree	1	212	2.96	3.9	0.76
2007	mid-	St.A	2	212	3.09	3.9	0.79
2007	mid-	Nat/tree	2	212	2.84	3.9	0.73
2007	mid-	tree	2	212	4.62	3.9	1.18
2007	mid-	native	2	212	2.67	3.9	0.68
2007	mid-	St.A/tree	2	212	2.06	3.9	0.53
2007	mid-	Nat/tree	3	212	3.06	3.9	0.78
2007	mid-	native	3	212	2.83	3.9	0.73
2007	mid-	tree	3	212	0.18	3.9	0.05
2007	mid-	St.A	3	212	1.63	3.9	0.42
2007	mid-	St.A/tree	3	212	2.72	3.9	0.70

2007	mid-	tree	1	216	0.45	4.9	0.09
2007	mid-	St.A	1	216	0.44	4.9	0.09
2007	mid-	St.A/tree	1	216	0.97	4.9	0.20
2007	mid-	native	1	216	0.00	4.9	0.00
2007	mid-	Nat/tree	1	216	2.66	4.9	0.54
2007	mid-	St.A	2	216	1.73	4.9	0.35
2007	mid-	Nat/tree	2	216	1.59	4.9	0.32
2007	mid-	tree	2	216	1.58	4.9	0.32
2007	mid-	native	2	216	2.19	4.9	0.45
2007	mid-	St.A/tree	2	216	2.34	4.9	0.48
2007	mid-	Nat/tree	3	216	1.26	4.9	0.26
2007	mid-	native	3	216	2.17	4.9	0.44
2007	mid-	tree	3	216	0.00	4.9	0.00
2007	mid-	St.A	3	216	3.39	4.9	0.69
2007	mid-	St.A/tree	3	216	1.28	4.9	0.26
2007	mid-	tree	1	227	2.00	4.8	0.42
2007	mid-	St.A	1	227	6.98	4.8	1.45
2007	mid-	St.A/tree	1	227	3.89	4.8	0.81
2007	mid-	native	1	227	1.51	4.8	0.31
2007	mid-	Nat/tree	1	227	3.38	4.8	0.70
2007	mid-	St.A	2	227	3.19	4.8	0.66
2007	mid-	Nat/tree	2	227	5.24	4.8	1.09
2007	mid-	tree	2	227	1.96	4.8	0.41
2007	mid-	native	2	227	4.29	4.8	0.89
2007	mid-	St.A/tree	2	227	2.24	4.8	0.47
2007	mid-	Nat/tree	3	227	4.63	4.8	0.96
2007	mid-	native	3	227	5.61	4.8	1.17
2007	mid-	tree	3	227	1.25	4.8	0.26
2007	mid-	St.A	3	227	1.12	4.8	0.23
2007	mid-	St.A/tree	3	227	2.94	4.8	0.61
2007	mid-	tree	1	242	2.88	4.4	0.65
2007	mid-	St.A	1	242	0.83	4.4	0.19
2007	mid-	St.A/tree	1	242	2.64	4.4	0.60
2007	mid-	native	1	242	0.88	4.4	0.20
2007	mid-	Nat/tree	1	242	2.47	4.4	0.56
2007	mid-	St.A	2	242	2.49	4.4	0.56
2007	mid-	Nat/tree	2	242	4.09	4.4	0.93
2007	mid-	tree	2	242	5.08	4.4	1.16
2007	mid-	native	2	242	2.95	4.4	0.67
2007	mid-	St.A/tree	2	242	2.25	4.4	0.51
2007	mid-	Nat/tree	3	242	3.92	4.4	0.89
2007	mid-	native	3	242	3.73	4.4	0.85
2007	mid-	tree	3	242	2.63	4.4	0.60
2007	mid-	St.A	3	242	1.46	4.4	0.33
2007	mid-	St.A/tree	3	242	2.90	4.4	0.66
2007	mid-	tree	1	254	1.50	4.2	0.36
2007	mid-	St.A	1	254	1.36	4.2	0.32
2007	mid-	St.A/tree	1	254	1.39	4.2	0.33

2007	mid-	native	1	254	1.26	4.2	0.30
2007	mid-	Nat/tree	1	254	3.13	4.2	0.75
2007	mid-	St.A	2	254	2.51	4.2	0.60
2007	mid-	Nat/tree	2	254	3.08	4.2	0.73
2007	mid-	tree	2	254	0.95	4.2	0.23
2007	mid-	native	2	254	2.84	4.2	0.68
2007	mid-	St.A/tree	2	254	1.52	4.2	0.36
2007	mid-	Nat/tree	3	254	3.59	4.2	0.86
2007	mid-	native	3	254	3.33	4.2	0.79
2007	mid-	tree	3	254	1.86	4.2	0.44
2007	mid-	St.A	3	254	1.64	4.2	0.39
2007	mid-	St.A/tree	3	254	2.11	4.2	0.50
2007	late-	tree	1	276	3.085	3.6	0.86
2007	late-	St.A	1	276	1.425	3.6	0.40
2007	late-	St.A/tree	1	276	2.83	3.6	0.79
2007	late-	native	1	276	1.775	3.6	0.49
2007	late-	Nat/tree	1	276	3.99	3.6	1.11
2007	late-	St.A	2	276	2.155	3.6	0.60
2007	late-	Nat/tree	2	276	2.42	3.6	0.67
2007	late-	tree	2	276	2.255	3.6	0.63
2007	late-	native	2	276	0	3.6	0.00
2007	late-	St.A/tree	2	276	1.21	3.6	0.34
2007	late-	Nat/tree	3	276	5.25	3.6	1.46
2007	late-	native	3	276	6.14	3.6	1.71
2007	late-	tree	3	276	3.63	3.6	1.01
2007	late-	St.A	3	276	2.355	3.6	0.65
2007	late-	St.A/tree	3	276	1.53	3.6	0.43
2007	late-	tree	1	285	2.65	3.4	0.78
2007	late-	St.A	1	285	1.49	3.4	0.44
2007	late-	St.A/tree	1	285	3.20	3.4	0.94
2007	late-	native	1	285	0.50	3.4	0.15
2007	late-	Nat/tree	1	285	2.09	3.4	0.61
2007	late-	St.A	2	285	2.42	3.4	0.71
2007	late-	Nat/tree	2	285	2.96	3.4	0.87
2007	late-	tree	2	285	2.37	3.4	0.70
2007	late-	native	2	285	1.95	3.4	0.57
2007	late-	St.A/tree	2	285	1.48	3.4	0.44
2007	late-	Nat/tree	3	285	3.09	3.4	0.91
2007	late-	native	3	285	4.46	3.4	1.31
2007	late-	tree	3	285	3.42	3.4	1.01
2007	late-	St.A	3	285	2.25	3.4	0.66
2007	late-	St.A/tree	3	285	2.16	3.4	0.64
2007	late-	tree	1	292	2.61	3.2	0.81
2007	late-	St.A	1	292	1.53	3.2	0.48
2007	late-	St.A/tree	1	292	2.75	3.2	0.86
2007	late-	native	1	292	1.98	3.2	0.62
2007	late-	Nat/tree	1	292	2.33	3.2	0.73
2007	late-	St.A	2	292	2.24	3.2	0.70

2007	late-	Nat/tree	2	292	3.98	3.2	1.24
2007	late-	tree	2	292	1.90	3.2	0.59
2007	late-	native	2	292	2.30	3.2	0.72
2007	late-	St.A/tree	2	292	1.62	3.2	0.51
2007	late-	Nat/tree	3	292	2.58	3.2	0.81
2007	late-	native	3	292	3.87	3.2	1.21
2007	late-	tree	3	292	1.61	3.2	0.50
2007	late-	St.A	3	292	2.67	3.2	0.83
2007	late-	St.A/tree	3	292	0.85	3.2	0.27
2007	late-	tree	1	299	1.40	2.7	0.52
2007	late-	St.A	1	299	0.97	2.7	0.36
2007	late-	St.A/tree	1	299	0.54	2.7	0.20
2007	late-	native	1	299	1.47	2.7	0.54
2007	late-	Nat/tree	1	299	3.56	2.7	1.32
2007	late-	St.A	2	299	1.74	2.7	0.64
2007	late-	Nat/tree	2	299	3.30	2.7	1.22
2007	late-	tree	2	299	0.93	2.7	0.34
2007	late-	native	2	299	2.59	2.7	0.96
2007	late-	St.A/tree	2	299	1.41	2.7	0.52
2007	late-	Nat/tree	3	299	3.10	2.7	1.15
2007	late-	native	3	299	0.54	2.7	0.20
2007	late-	tree	3	299	0.00	2.7	0.00
2007	late-	St.A	3	299	1.47	2.7	0.54
2007	late-	St.A/tree	3	299	1.35	2.7	0.50
2007	late-	tree	1	308	2.00	2.3	0.87
2007	late-	St.A	1	308	0.70	2.3	0.30
2007	late-	St.A/tree	1	308	0.90	2.3	0.39
2007	late-	native	1	308	0.52	2.3	0.23
2007	late-	Nat/tree	1	308	2.07	2.3	0.90
2007	late-	St.A	2	308	1.37	2.3	0.59
2007	late-	Nat/tree	2	308	1.73	2.3	0.75
2007	late-	tree	2	308	0.53	2.3	0.23
2007	late-	native	2	308	1.19	2.3	0.52
2007	late-	St.A/tree	2	308	0.94	2.3	0.41
2007	late-	Nat/tree	3	308	1.44	2.3	0.63
2007	late-	native	3	308	0.91	2.3	0.40
2007	late-	tree	3	308	2.07	2.3	0.90
2007	late-	St.A	3	308	0.92	2.3	0.40
2007	late-	St.A/tree	3	308	0.63	2.3	0.27
2007	late-	tree	1	320	2.31	2.7	0.86
2007	late-	St.A	1	320	1.18	2.7	0.44
2007	late-	St.A/tree	1	320	2.78	2.7	1.03
2007	late-	native	1	320	1.61	2.7	0.60
2007	late-	Nat/tree	1	320	2.39	2.7	0.88
2007	late-	St.A	2	320	2.30	2.7	0.85
2007	late-	Nat/tree	2	320	3.56	2.7	1.32
2007	late-	tree	2	320	1.74	2.7	0.65
2007	late-	native	2	320	2.24	2.7	0.83

2007	late-	St.A/tree	2	320	1.86	2.7	0.69
2007	late-	Nat/tree	3	320	3.35	2.7	1.24
2007	late-	native	3	320	2.73	2.7	1.01
2007	late-	tree	3	320	0.78	2.7	0.29
2007	late-	St.A	3	320	1.47	2.7	0.54
2007	late-	St.A/tree	3	320	1.85	2.7	0.69
2008	early-	tree	1	81	0.33	4.60	0.07
2008	early-	St.A	1	81	2.94	4.60	0.64
2008	early-	St.Atree	1	81	2.57	4.60	0.56
2008	early-	native	1	81	1.82	4.60	0.39
2008	early-	Nat/tree	1	81	1.54	4.60	0.33
2008	early-	St.A	2	81	2.17	4.60	0.47
2008	early-	Nat/tree	2	81	1.92	4.60	0.42
2008	early-	tree	2	81	1.02	4.60	0.22
2008	early-	native	2	81	1.90	4.60	0.41
2008	early-	St.A/tree	2	81	2.39	4.60	0.52
2008	early-	Nat/tree	3	81	2.72	4.60	0.59
2008	early-	native	3	81	1.24	4.60	0.27
2008	early-	tree	3	81	0.76	4.60	0.17
2008	early-	St.A	3	81	1.91	4.60	0.42
2008	early-	St.A/tree	3	81	1.90	4.60	0.41
2008	early-	tree	1	94	1.93	3.30	0.59
2008	early-	St.A	1	94	0.83	3.30	0.25
2008	early-	St.Atree	1	94	1.70	3.30	0.51
2008	early-	native	1	94	0.00	3.30	0.00
2008	early-	Nat/tree	1	94	1.95	3.30	0.59
2008	early-	St.A	2	94	1.40	3.30	0.42
2008	early-	Nat/tree	2	94	1.43	3.30	0.43
2008	early-	tree	2	94	1.43	3.30	0.43
2008	early-	native	2	94	0.72	3.30	0.22
2008	early-	St.A/tree	2	94	0.99	3.30	0.30
2008	early-	Nat/tree	3	94	1.52	3.30	0.46
2008	early-	native	3	94	1.34	3.30	0.41
2008	early-	tree	3	94	0.43	3.30	0.13
2008	early-	St.A	3	94	1.37	3.30	0.41
2008	early-	St.A/tree	3	94	0.85	3.30	0.26
2008	early-	tree	1	115	0.234	3.9	0.06
2008	early-	St.A	1	115	0.74	3.90	0.19
2008	early-	St.Atree	1	115	2.09	3.90	0.54
2008	early-	native	1	115	0.17	3.90	0.04
2008	early-	Nat/tree	1	115	0.35	3.90	0.09
2008	early-	St.A	2	115	0.63	3.90	0.16
2008	early-	Nat/tree	2	115	0.51	3.90	0.13
2008	early-	tree	2	115	0.28	3.90	0.07
2008	early-	native	2	115	0.47	3.90	0.12
2008	early-	St.A/tree	2	115	0.79	3.90	0.20
2008	early-	Nat/tree	3	115	0.87	3.90	0.22

2008	early-	native	3	115	0.88	3.90	0.23
2008	early-	tree	3	115	0.54	3.90	0.14
2008	early-	St.A	3	115	1.12	3.90	0.29
2008	early-	St.A/tree	3	115	2.17	3.90	0.56
2008	early-	tree	1	121	1.34	4.90	0.27
2008	early-	St.A	1	121	1.75	4.90	0.36
2008	early-	St.Atree	1	121	5.70	4.90	1.16
2008	early-	native	1	121	0.38	4.90	0.08
2008	early-	Nat/tree	1	121	1.44	4.90	0.29
2008	early-	St.A	2	121	3.26	4.90	0.66
2008	early-	Nat/tree	2	121	2.66	4.90	0.54
2008	early-	tree	2	121	1.65	4.90	0.34
2008	early-	native	2	121	2.62	4.90	0.54
2008	early-	St.A/tree	2	121	3.47	4.90	0.71
2008	early-	Nat/tree	3	121	3.12	4.90	0.64
2008	early-	native	3	121	1.68	4.90	0.34
2008	early-	tree	3	121	1.72	4.90	0.35
2008	early-	St.A	3	121	2.46	4.90	0.50
2008	early-	St.A/tree	3	121	3.83	4.90	0.78
2008	early-	tree	1	129	0.39	5.40	0.07
2008	early-	St.A	1	129	4.15	5.40	0.77
2008	early-	St.Atree	1	129	3.25	5.40	0.60
2008	early-	native	1	129	0.25	5.40	0.05
2008	early-	Nat/tree	1	129	0.46	5.40	0.09
2008	early-	St.A	2	129	2.31	5.40	0.43
2008	early-	Nat/tree	2	129	0.43	5.40	0.08
2008	early-	tree	2	129	1.13	5.40	0.21
2008	early-	native	2	129	1.24	5.40	0.23
2008	early-	St.A/tree	2	129	2.24	5.40	0.41
2008	early-	Nat/tree	3	129	1.33	5.40	0.25
2008	early-	native	3	129	0.89	5.40	0.16
2008	early-	tree	3	129	0.34	5.40	0.06
2008	early-	St.A	3	129	1.89	5.40	0.35
2008	early-	St.A/tree	3	129	2.46	5.40	0.45
2008	early-	tree	1	144	3.06	6.70	0.46
2008	early-	St.A	1	144	3.63	6.70	0.54
2008	early-	St.Atree	1	144	7.10	6.70	1.06
2008	early-	native	1	144	3.33	6.70	0.50
2008	early-	Nat/tree	1	144	1.50	6.70	0.22
2008	early-	St.A	2	144	4.06	6.70	0.61
2008	early-	Nat/tree	2	144	0.57	6.70	0.09
2008	early-	tree	2	144	1.73	6.70	0.26
2008	early-	native	2	144	2.28	6.70	0.34
2008	early-	St.A/tree	2	144	3.06	6.70	0.46
2008	early-	Nat/tree	3	144	2.35	6.70	0.35
2008	early-	native	3	144	3.04	6.70	0.45
2008	early-	tree	3	144	1.21	6.70	0.18
2008	early-	St.A	3	144	2.24	6.70	0.33

2008	early-	St.A/tree	3	144	4.19	6.70	0.63
2008	mid-	tree	1	151	0.71	6.20	0.12
2008	mid-	St.A	1	151	3.05	6.20	0.49
2008	mid-	St.Atree	1	151	4.64	6.20	0.75
2008	mid-	native	1	151	2.95	6.20	0.48
2008	mid-	Nat/tree	1	151	2.63	6.20	0.42
2008	mid-	St.A	2	151	5.46	6.20	0.88
2008	mid-	Nat/tree	2	151	2.25	6.20	0.36
2008	mid-	tree	2	151	2.45	6.20	0.40
2008	mid-	native	2	151	3.99	6.20	0.64
2008	mid-	St.A/tree	2	151	4.98	6.20	0.80
2008	mid-	Nat/tree	3	151	3.41	6.20	0.55
2008	mid-	native	3	151	2.41	6.20	0.39
2008	mid-	tree	3	151	1.09	6.20	0.18
2008	mid-	St.A	3	151	4.00	6.20	0.64
2008	mid-	St.A/tree	3	151	3.21	6.20	0.52
2008	mid-	tree	1	158	1.09	6.70	0.16
2008	mid-	St.A	1	158	3.90	6.70	0.58
2008	mid-	St.Atree	1	158	5.01	6.70	0.75
2008	mid-	native	1	158	2.92	6.70	0.44
2008	mid-	Nat/tree	1	158	2.84	6.70	0.42
2008	mid-	St.A	2	158	4.45	6.70	0.66
2008	mid-	Nat/tree	2	158	2.53	6.70	0.38
2008	mid-	tree	2	158	2.32	6.70	0.35
2008	mid-	native	2	158	3.58	6.70	0.53
2008	mid-	St.A/tree	2	158	5.07	6.70	0.76
2008	mid-	Nat/tree	3	158	3.17	6.70	0.47
2008	mid-	native	3	158	1.75	6.70	0.26
2008	mid-	tree	3	158	1.48	6.70	0.22
2008	mid-	St.A	3	158	2.84	6.70	0.42
2008	mid-	St.A/tree	3	158	2.27	6.70	0.34
2008	mid-	tree	1	165	1.18	6.70	0.18
2008	mid-	St.A	1	165	3.84	6.70	0.57
2008	mid-	St.Atree	1	165	6.04	6.70	0.90
2008	mid-	native	1	165	6.70	6.70	1.00
2008	mid-	Nat/tree	1	165	1.87	6.70	0.28
2008	mid-	St.A	2	165	5.75	6.70	0.86
2008	mid-	Nat/tree	2	165	1.51	6.70	0.22
2008	mid-	tree	2	165	2.69	6.70	0.40
2008	mid-	native	2	165	3.54	6.70	0.53
2008	mid-	St.A/tree	2	165	5.10	6.70	0.76
2008	mid-	Nat/tree	3	165	3.17	6.70	0.47
2008	mid-	native	3	165	1.86	6.70	0.28
2008	mid-	tree	3	165	1.48	6.70	0.22
2008	mid-	St.A	3	165	2.85	6.70	0.43
2008	mid-	St.A/tree	3	165	2.02	6.70	0.30
2008	mid-	tree	1	172	1.04	6.4	0.16
2008	mid-	St.A	1	172	2.22	6.40	0.35

2008	mid-	St.Atree	1	172	7.10	6.40	1.11
2008	mid-	native	1	172	7.25	6.40	1.13
2008	mid-	Nat/tree	1	172	2.27	6.40	0.35
2008	mid-	St.A	2	172	3.44	6.40	0.54
2008	mid-	Nat/tree	2	172	3.65	6.40	0.57
2008	mid-	tree	2	172	3.16	6.40	0.49
2008	mid-	native	2	172	3.71	6.40	0.58
2008	mid-	St.A/tree	2	172	2.00	6.40	0.31
2008	mid-	Nat/tree	3	172	3.06	6.40	0.48
2008	mid-	native	3	172	5.43	6.40	0.85
2008	mid-	tree	3	172	1.90	6.40	0.30
2008	mid-	St.A	3	172	2.95	6.40	0.46
2008	mid-	St.A/tree	3	172	4.26	6.40	0.67
2008	mid-	tree	1	179	0.90	6.40	0.14
2008	mid-	St.A	1	179	2.42	6.40	0.38
2008	mid-	St.Atree	1	179	5.25	6.40	0.82
2008	mid-	native	1	179	11.06	6.40	1.73
2008	mid-	Nat/tree	1	179	2.66	6.40	0.42
2008	mid-	St.A	2	179	2.97	6.40	0.46
2008	mid-	Nat/tree	2	179	5.12	6.40	0.80
2008	mid-	tree	2	179	2.02	6.40	0.31
2008	mid-	native	2	179	1.84	6.40	0.29
2008	mid-	St.A/tree	2	179	4.22	6.40	0.66
2008	mid-	Nat/tree	3	179	1.06	6.40	0.17
2008	mid-	native	3	179	7.27	6.40	1.14
2008	mid-	tree	3	179	1.69	6.40	0.26
2008	mid-	St.A	3	179	3.13	6.40	0.49
2008	mid-	St.A/tree	3	179	4.22	6.40	0.66
2008	mid-	tree	1	200	0.90	6.00	0.15
2008	mid-	St.A	1	200	1.78	6.00	0.30
2008	mid-	St.Atree	1	200	2.13	6.00	0.36
2008	mid-	native	1	200	4.71	6.00	0.78
2008	mid-	Nat/tree	1	200	4.71	6.00	0.79
2008	mid-	St.A	2	200	2.63	6.00	0.44
2008	mid-	Nat/tree	2	200	4.96	6.00	0.83
2008	mid-	tree	2	200	1.97	6.00	0.33
2008	mid-	native	2	200	5.33	6.00	0.89
2008	mid-	St.A/tree	2	200	5.12	6.00	0.85
2008	mid-	Nat/tree	3	200	4.60	6.00	0.77
2008	mid-	native	3	200	6.82	6.00	1.14
2008	mid-	tree	3	200	1.76	6.00	0.29
2008	mid-	St.A	3	200	2.23	6.00	0.37
2008	mid-	St.A/tree	3	200	1.40	6.00	0.23
2008	mid-	tree	1	214	1.34	5.50	0.24
2008	mid-	St.A	1	214	1.59	5.50	0.29
2008	mid-	St.Atree	1	214	2.35	5.50	0.43
2008	mid-	native	1	214	3.63	5.50	0.66
2008	mid-	Nat/tree	1	214	4.18	5.50	0.76

2008	mid-	St.A	2	214	1.26	5.50	0.23
2008	mid-	Nat/tree	2	214	3.99	5.50	0.73
2008	mid-	tree	2	214	1.06	5.50	0.19
2008	mid-	native	2	214	4.09	5.50	0.74
2008	mid-	St.A/tree	2	214	2.73	5.50	0.50
2008	mid-	Nat/tree	3	214	2.91	5.50	0.53
2008	mid-	native	3	214	2.69	5.50	0.49
2008	mid-	tree	3	214	1.46	5.50	0.26
2008	mid-	St.A	3	214	1.82	5.50	0.33
2008	mid-	St.A/tree	3	214	1.08	5.50	0.20
2008	mid-	tree	1	222	1.61	6.00	0.27
2008	mid-	St.A	1	222	4.50	6.00	0.75
2008	mid-	St.Atree	1	222	5.39	6.00	0.90
2008	mid-	native	1	222	7.82	6.00	1.30
2008	mid-	Nat/tree	1	222	2.95	6.00	0.49
2008	mid-	St.A	2	222	4.27	6.00	0.71
2008	mid-	Nat/tree	2	222	5.56	6.00	0.93
2008	mid-	tree	2	222	1.77	6.00	0.30
2008	mid-	native	2	222	5.69	6.00	0.95
2008	mid-	St.A/tree	2	222	5.16	6.00	0.86
2008	mid-	Nat/tree	3	222	3.56	6.00	0.59
2008	mid-	native	3	222	0.61	6.00	0.10
2008	mid-	tree	3	222	2.05	6.00	0.34
2008	mid-	St.A	3	222	3.76	6.00	0.63
2008	mid-	St.A/tree	3	222	3.00	6.00	0.50
2008	late-	tree	1	262	2.25	3.7	0.61
2008	late-	St.A	1	262	3.71	3.7	1.00
2008	late-	St.Atree	1	262	5.37	3.7	1.45
2008	late-	native	1	262	5.48	3.7	1.48
2008	late-	Nat/tree	1	262	2.44	3.7	0.66
2008	late-	St.A	2	262	3.01	3.7	0.81
2008	late-	Nat/tree	2	262	5.05	3.7	1.36
2008	late-	tree	2	262	2.87	3.7	0.78
2008	late-	native	2	262	5.72	3.7	1.55
2008	late-	St.A/tree	2	262	3.42	3.70	0.92
2008	late-	Nat/tree	3	262	3.09	3.70	0.84
2008	late-	native	3	262	3.09	3.70	0.83
2008	late-	tree	3	262	3.39	3.70	0.92
2008	late-	St.A	3	262	2.49	3.70	0.67
2008	late-	St.A/tree	3	262	3.05	3.70	0.82
2008	late-	tree	1	269	2.47	4.60	0.54
2008	late-	St.A	1	269	3.30	4.60	0.72
2008	late-	St.Atree	1	269	4.32	4.60	0.94
2008	late-	native	1	269	3.55	4.60	0.77
2008	late-	Nat/tree	1	269	0.83	4.60	0.18
2008	late-	St.A	2	269	2.36	4.60	0.51
2008	late-	Nat/tree	2	269	4.03	4.60	0.88
2008	late-	tree	2	269	2.56	4.60	0.56

2008	late-	native	2	269	4.74	4.60	1.03
2008	late-	St.A/tree	2	269	2.18	4.60	0.47
2008	late-	Nat/tree	3	269	2.27	4.60	0.49
2008	late-	native	3	269	2.78	4.60	0.60
2008	late-	tree	3	269	2.62	4.60	0.57
2008	late-	St.A	3	269	2.22	4.60	0.48
2008	late-	St.A/tree	3	269	2.88	4.60	0.63
2008	late-	tree	1	283	1.17	3.40	0.34
2008	late-	St.A	1	283	3.12	3.40	0.92
2008	late-	St.Atree	1	283	4.04	3.40	1.19
2008	late-	native	1	283	2.97	3.40	0.87
2008	late-	Nat/tree	1	283	1.08	3.40	0.32
2008	late-	St.A	2	283	2.84	3.40	0.84
2008	late-	Nat/tree	2	283	3.58	3.40	1.05
2008	late-	tree	2	283	1.72	3.40	0.51
2008	late-	native	2	283	5.26	3.40	1.55
2008	late-	St.A/tree	2	283	2.94	3.40	0.86
2008	late-	Nat/tree	3	283	3.00	3.40	0.88
2008	late-	native	3	283	0.00	3.40	-0.01
2008	late-	tree	3	283	2.39	3.40	0.70
2008	late-	St.A	3	283	3.07	3.40	0.90
2008	late-	St.A/tree	3	283	3.66	3.40	1.08
2008	late-	tree	1	296	2.83	3.20	0.88
2008	late-	St.A	1	296	1.68	3.20	0.52
2008	late-	St.Atree	1	296	2.91	3.20	0.91
2008	late-	native	1	296	4.03	3.20	1.26
2008	late-	Nat/tree	1	296	0.74	3.20	0.23
2008	late-	St.A	2	296	0.67	3.20	0.21
2008	late-	Nat/tree	2	296	0.31	3.20	0.10
2008	late-	tree	2	296	1.76	3.20	0.55
2008	late-	native	2	296	2.57	3.20	0.80
2008	late-	St.A/tree	2	296	0.86	3.20	0.27
2008	late-	Nat/tree	3	296	0.59	3.20	0.18
2008	late-	native	3	296	0.63	3.20	0.20
2008	late-	tree	3	296	2.31	3.20	0.72
2008	late-	St.A	3	296	0.98	3.20	0.31
2008	late-	St.A/tree	3	296	1.44	3.20	0.45

APPENDIX D

COLLEGE STATION WATER USE DATA

year	season	plant treatment	BLOCK	day of year	actual H_2O (mm) use/drydown	avg RET (mm) day/drydown	K_L
2007	early-	tree	1	84	0.52	3.3	0.16
2007	early-	bermuda	1	84	0.62	3.3	0.19
2007	early-	Nat/tree	1	84	0.47	3.3	0.14
2007	early-	St.A	1	84	0.25	3.3	0.08
2007	early-	native	1	84	1.02	3.3	0.31
2007	early-	St.A/tree	1	84	0.43	3.3	0.13
2007	early-	St.A	2	84	1.51	3.3	0.46
2007	early-	Nat/tree	2	84	0.35	3.3	0.10
2007	early-	native	2	84	0.39	3.3	0.12
2007	early-	tree	2	84	1.08	3.3	0.33
2007	early-	bermuda	2	84	0.77	3.3	0.23
2007	early-	St.A/tree	2	84	1.24	3.3	0.38
2007	early-	bermuda	3	84	1.00	3.3	0.30
2007	early-	tree	3	84	0.75	3.3	0.23
2007	early-	native	3	84	0.58	3.3	0.18
2007	early-	St.A/tree	3	84	2.76	3.3	0.84
2007	early-	St.A	3	84	1.45	3.3	0.44
2007	early-	Nat/tree	3	84	1.30	3.3	0.39
2007	early-	tree	1	88	0.29	3.7	0.08
2007	early-	bermuda	1	88	0.52	3.7	0.14
2007	early-	Nat/tree	1	88	1.18	3.7	0.32
2007	early-	St.A	1	88	1.62	3.7	0.44
2007	early-	native	1	88	1.21	3.7	0.33
2007	early-	St.A/tree	1	88	0.93	3.7	0.25
2007	early-	St.A	2	88	0.00	3.7	0.00
2007	early-	Nat/tree	2	88	1.10	3.7	0.30
2007	early-	native	2	88	1.06	3.7	0.29
2007	early-	tree	2	88	0.37	3.7	0.10
2007	early-	bermuda	2	88	0.00	3.7	0.00
2007	early-	St.A/tree	2	88	0.83	3.7	0.23
2007	early-	bermuda	3	88	0.32	3.7	0.09
2007	early-	tree	3	88	0.38	3.7	0.10
2007	early-	native	3	88	1.06	3.7	0.29
2007	early-	St.A/tree	3	88	0.00	3.7	0.00
2007	early-	St.A	3	88	0.00	3.7	0.00
2007	early-	Nat/tree	3	88	0.93	3.7	0.25
2007	early-	tree	1	112	0.00	4.3	0.00
2007	early-	bermuda	1	112	0.00	4.3	0.00

2007	early-	Nat/tree	1	112	0.00	4.3	0.00
2007	early-	St.A	1	112	0.65	4.3	0.15
2007	early-	native	1	112	1.26	4.3	0.29
2007	early-	St.A/tree	1	112	0.94	4.3	0.22
2007	early-	St.A	2	112	0.69	4.3	0.16
2007	early-	Nat/tree	2	112	0.86	4.3	0.20
2007	early-	native	2	112	0.10	4.3	0.02
2007	early-	tree	2	112	0.18	4.3	0.04
2007	early-	bermuda	2	112	1.53	4.3	0.36
2007	early-	St.A/tree	2	112	0.00	4.3	0.00
2007	early-	bermuda	3	112	0.00	4.3	0.00
2007	early-	tree	3	112	0.00	4.3	0.00
2007	early-	native	3	112	0.30	4.3	0.07
2007	early-	St.A/tree	3	112	0.53	4.3	0.12
2007	early-	St.A	3	112	0.65	4.3	0.15
2007	early-	Nat/tree	3	112	0.42	4.3	0.10
2007	early-	tree	1	118	0.00	3.9	0.00
2007	early-	bermuda	1	118	0.84	3.9	0.22
2007	early-	Nat/tree	1	118	1.33	3.9	0.34
2007	early-	St.A	1	118	0.82	3.9	0.21
2007	early-	native	1	118	1.20	3.9	0.31
2007	early-	St.A/tree	1	118	1.03	3.9	0.26
2007	early-	St.A	2	118	0.05	3.9	0.01
2007	early-	Nat/tree	2	118	0.29	3.9	0.07
2007	early-	native	2	118	0.00	3.9	0.00
2007	early-	tree	2	118	0.11	3.9	0.03
2007	early-	bermuda	2	118	0.69	3.9	0.18
2007	early-	St.A/tree	2	118	1.47	3.9	0.38
2007	early-	bermuda	3	118	0.61	3.9	0.16
2007	early-	tree	3	118	1.09	3.9	0.28
2007	early-	native	3	118	0.45	3.9	0.11
2007	early-	St.A/tree	3	118	1.65	3.9	0.42
2007	early-	St.A	3	118	0.65	3.9	0.17
2007	early-	Nat/tree	3	118	0.59	3.9	0.15
2007	early-	tree	1	125	0.54	1.3	0.41
2007	early-	bermuda	1	125	0.00	1.3	0.00
2007	early-	Nat/tree	1	125	3.29	1.3	2.53
2007	early-	St.A	1	125	5.61	1.3	4.31
2007	early-	native	1	125	5.59	1.3	4.30
2007	early-	St.A/tree	1	125	3.26	1.3	2.50
2007	early-	St.A	2	125	0.62	1.3	0.48
2007	early-	Nat/tree	2	125	1.03	1.3	0.79
2007	early-	native	2	125	0.35	1.3	0.27
2007	early-	tree	2	125	0.25	1.3	0.19
2007	early-	bermuda	2	125	2.13	1.3	1.63
2007	early-	St.A/tree	2	125	1.57	1.3	1.20
2007	early-	bermuda	3	125	0.06	1.3	0.05
2007	early-	tree	3	125	0.30	1.3	0.23

2007	early-	native	3	125	0.52	1.3	0.40
2007	early-	St.A/tree	3	125	2.33	1.3	1.79
2007	early-	St.A	3	125	2.77	1.3	2.13
2007	early-	Nat/tree	3	125	2.01	1.3	1.54
2007	early-	tree	1	153	0.00	4.2	0.00
2007	early-	bermuda	1	153	0.87	4.2	0.21
2007	early-	Nat/tree	1	153	0.66	4.2	0.16
2007	early-	St.A	1	153	0.87	4.2	0.21
2007	early-	native	1	153	2.53	4.2	0.60
2007	early-	St.A/tree	1	153	2.41	4.2	0.57
2007	early-	St.A	2	153	2.47	4.2	0.59
2007	early-	Nat/tree	2	153	2.55	4.2	0.61
2007	early-	native	2	153	0.95	4.2	0.23
2007	early-	tree	2	153	1.09	4.2	0.26
2007	early-	bermuda	2	153	1.37	4.2	0.33
2007	early-	St.A/tree	2	153	1.38	4.2	0.33
2007	early-	bermuda	3	153	1.86	4.2	0.44
2007	early-	tree	3	153	1.05	4.2	0.25
2007	early-	native	3	153	1.19	4.2	0.28
2007	early-	St.A/tree	3	153	1.82	4.2	0.43
2007	early-	St.A	3	153	2.61	4.2	0.62
2007	early-	Nat/tree	3	153	1.14	4.2	0.27
2007	mid-	tree	1	163	0.37	4.6	0.08
2007	mid-	bermuda	1	163	0.59	4.6	0.13
2007	mid-	Nat/tree	1	163	1.11	4.6	0.24
2007	mid-	St.A	1	163	1.96	4.6	0.43
2007	mid-	native	1	163	1.64	4.6	0.36
2007	mid-	St.A/tree	1	163	1.79	4.6	0.39
2007	mid-	St.A	2	163	2.06	4.6	0.45
2007	mid-	Nat/tree	2	163	1.45	4.6	0.32
2007	mid-	native	2	163	1.55	4.6	0.34
2007	mid-	tree	2	163	1.41	4.6	0.31
2007	mid-	bermuda	2	163	2.14	4.6	0.47
2007	mid-	St.A/tree	2	163	1.37	4.6	0.30
2007	mid-	bermuda	3	163	1.33	4.6	0.29
2007	mid-	tree	3	163	0.76	4.6	0.17
2007	mid-	native	3	163	0.82	4.6	0.18
2007	mid-	St.A/tree	3	163	2.43	4.6	0.53
2007	mid-	St.A	3	163	0.36	4.6	0.08
2007	mid-	Nat/tree	3	163	1.02	4.6	0.22
2007	mid-	tree	1	194	0.26	4.5	0.06
2007	mid-	bermuda	1	194	0.67	4.5	0.15
2007	mid-	Nat/tree	1	194	1.17	4.5	0.26
2007	mid-	St.A	1	194	0.96	4.5	0.21
2007	mid-	native	1	194	0.82	4.5	0.18
2007	mid-	St.A/tree	1	194	0.44	4.5	0.10
2007	mid-	St.A	2	194	1.36	4.5	0.30
2007	mid-	Nat/tree	2	194	2.29	4.5	0.51

2007	mid-	native	2	194	2.19	4.5	0.49
2007	mid-	tree	2	194	0.82	4.5	0.18
2007	mid-	bermuda	2	194	3.27	4.5	0.73
2007	mid-	St.A/tree	2	194	0.82	4.5	0.18
2007	mid-	bermuda	3	194	1.31	4.5	0.29
2007	mid-	tree	3	194	0.81	4.5	0.18
2007	mid-	native	3	194	2.84	4.5	0.63
2007	mid-	St.A/tree	3	194	2.36	4.5	0.52
2007	mid-	St.A	3	194	1.74	4.5	0.39
2007	mid-	Nat/tree	3	194	2.42	4.5	0.54
2007	mid-	tree	1	200	0.66	5.2	0.13
2007	mid-	bermuda	1	200	0.61	5.2	0.12
2007	mid-	Nat/tree	1	200	1.42	5.2	0.27
2007	mid-	St.A	1	200	0.41	5.2	0.08
2007	mid-	native	1	200	1.17	5.2	0.23
2007	mid-	St.A/tree	1	200	0.72	5.2	0.14
2007	mid-	St.A	2	200	0.71	5.2	0.14
2007	mid-	Nat/tree	2	200	2.54	5.2	0.49
2007	mid-	native	2	200	1.99	5.2	0.38
2007	mid-	tree	2	200	0.52	5.2	0.10
2007	mid-	bermuda	2	200	3.95	5.2	0.76
2007	mid-	St.A/tree	2	200	1.90	5.2	0.37
2007	mid-	bermuda	3	200	0.63	5.2	0.12
2007	mid-	tree	3	200	1.56	5.2	0.30
2007	mid-	native	3	200	1.23	5.2	0.24
2007	mid-	St.A/tree	3	200	1.19	5.2	0.23
2007	mid-	St.A	3	200	0.00	5.2	0.00
2007	mid-	Nat/tree	3	200	2.21	5.2	0.43
2007	mid-	tree	1	213	0.28	3.6	0.08
2007	mid-	bermuda	1	213	0.13	3.6	0.04
2007	mid-	Nat/tree	1	213	1.29	3.6	0.36
2007	mid-	St.A	1	213	1.56	3.6	0.43
2007	mid-	native	1	213	1.63	3.6	0.45
2007	mid-	St.A/tree	1	213	1.93	3.6	0.54
2007	mid-	St.A	2	213	1.32	3.6	0.37
2007	mid-	Nat/tree	2	213	4.32	3.6	1.20
2007	mid-	native	2	213	2.08	3.6	0.58
2007	mid-	tree	2	213	0.83	3.6	0.23
2007	mid-	bermuda	2	213	2.00	3.6	0.56
2007	mid-	St.A/tree	2	213	0.37	3.6	0.10
2007	mid-	bermuda	3	213	1.21	3.6	0.33
2007	mid-	tree	3	213	0.54	3.6	0.15
2007	mid-	native	3	213	2.39	3.6	0.66
2007	mid-	St.A/tree	3	213	1.32	3.6	0.37
2007	mid-	St.A	3	213	1.56	3.6	0.43
2007	mid-	Nat/tree	3	213	0.70	3.6	0.20
2007	mid-	tree	1	221	0.69	4.4	0.16
2007	mid-	bermuda	1	221	1.14	4.4	0.26

2007	mid-	Nat/tree	1	221	1.51	4.4	0.34
2007	mid-	St.A	1	221	1.57	4.4	0.36
2007	mid-	native	1	221	2.35	4.4	0.53
2007	mid-	St.A/tree	1	221	3.28	4.4	0.75
2007	mid-	St.A	2	221	1.63	4.4	0.37
2007	mid-	Nat/tree	2	221	6.10	4.4	1.39
2007	mid-	native	2	221	2.78	4.4	0.63
2007	mid-	tree	2	221	2.93	4.4	0.66
2007	mid-	bermuda	2	221	4.66	4.4	1.06
2007	mid-	St.A/tree	2	221	1.71	4.4	0.39
2007	mid-	bermuda	3	221	1.58	4.4	0.36
2007	mid-	tree	3	221	0.80	4.4	0.18
2007	mid-	native	3	221	2.43	4.4	0.55
2007	mid-	St.A/tree	3	221	2.38	4.4	0.54
2007	mid-	St.A	3	221	1.82	4.4	0.41
2007	mid-	Nat/tree	3	221	1.46	4.4	0.33
2007	mid-	tree	1	236	0.16	5.3	0.03
2007	mid-	bermuda	1	236	0.78	5.3	0.15
2007	mid-	Nat/tree	1	236	1.25	5.3	0.24
2007	mid-	St.A	1	236	1.92	5.3	0.36
2007	mid-	native	1	236	1.07	5.3	0.20
2007	mid-	St.A/tree	1	236	0.67	5.3	0.13
2007	mid-	St.A	2	236	0.36	5.3	0.07
2007	mid-	Nat/tree	2	236	4.66	5.3	0.88
2007	mid-	native	2	236	2.08	5.3	0.39
2007	mid-	tree	2	236	1.71	5.3	0.32
2007	mid-	bermuda	2	236	4.91	5.3	0.93
2007	mid-	St.A/tree	2	236	1.58	5.3	0.30
2007	mid-	bermuda	3	236	0.60	5.3	0.11
2007	mid-	tree	3	236	0.74	5.3	0.14
2007	mid-	native	3	236	2.13	5.3	0.40
2007	mid-	St.A/tree	3	236	1.94	5.3	0.37
2007	mid-	St.A	3	236	0.00	5.3	0.00
2007	mid-	Nat/tree	3	236	0.99	5.3	0.19
2007	mid-	tree	1	259	0.54	3.6	0.15
2007	mid-	bermuda	1	259	1.53	3.6	0.42
2007	mid-	Nat/tree	1	259	1.26	3.6	0.35
2007	mid-	St.A	1	259	0.70	3.6	0.19
2007	mid-	native	1	259	2.23	3.6	0.62
2007	mid-	St.A/tree	1	259	1.98	3.6	0.55
2007	mid-	St.A	2	259	1.02	3.6	0.28
2007	mid-	Nat/tree	2	259	3.07	3.6	0.85
2007	mid-	native	2	259	3.05	3.6	0.85
2007	mid-	tree	2	259	1.10	3.6	0.31
2007	mid-	bermuda	2	259	5.59	3.6	1.55
2007	mid-	St.A/tree	2	259	0.12	3.6	0.03
2007	mid-	bermuda	3	259	1.80	3.6	0.50
2007	mid-	tree	3	259	0.65	3.6	0.18

2007	mid-	native	3	259	1.29	3.6	0.36
2007	mid-	St.A/tree	3	259	1.72	3.6	0.48
2007	mid-	St.A	3	259	0.00	3.6	0.00
2007	mid-	Nat/tree	3	259	1.15	3.6	0.32
2007	late-	tree	1	278	0.12	4	0.03
2007	late-	bermuda	1	278	0.82	4	0.21
2007	late-	Nat/tree	1	278	0.00	4	0.00
2007	late-	St.A	1	278	1.73	4	0.43
2007	late-	native	1	278	1.20	4	0.30
2007	late-	St.A/tree	1	278	2.92	4	0.73
2007	late-	St.A	2	278	1.78	4	0.44
2007	late-	Nat/tree	2	278	2.07	4	0.52
2007	late-	native	2	278	0.14	4	0.03
2007	late-	tree	2	278	0.86	4	0.21
2007	late-	bermuda	2	278	2.99	4	0.75
2007	late-	St.A/tree	2	278	0.28	4	0.07
2007	late-	bermuda	3	278	1.09	4	0.27
2007	late-	tree	3	278	0.53	4	0.13
2007	late-	native	3	278	0.00	4	0.00
2007	late-	St.A/tree	3	278	1.27	4	0.32
2007	late-	St.A	3	278	0.00	4	0.00
2007	late-	Nat/tree	3	278	0.00	4	0.00
2007	late-	tree	1	284	2.01	3.9	0.51
2007	late-	bermuda	1	284	0.63	3.9	0.16
2007	late-	Nat/tree	1	284	0.00	3.9	0.00
2007	late-	St.A	1	284	1.80	3.9	0.46
2007	late-	native	1	284	1.35	3.9	0.35
2007	late-	St.A/tree	1	284	2.44	3.9	0.63
2007	late-	St.A	2	284	1.94	3.9	0.50
2007	late-	Nat/tree	2	284	5.60	3.9	1.44
2007	late-	native	2	284	0.67	3.9	0.17
2007	late-	tree	2	284	1.76	3.9	0.45
2007	late-	bermuda	2	284	2.17	3.9	0.56
2007	late-	St.A/tree	2	284	0.42	3.9	0.11
2007	late-	bermuda	3	284	1.05	3.9	0.27
2007	late-	tree	3	284	0.49	3.9	0.13
2007	late-	native	3	284	0.43	3.9	0.11
2007	late-	St.A/tree	3	284	1.41	3.9	0.36
2007	late-	St.A	3	284	0.21	3.9	0.06
2007	late-	Nat/tree	3	284	0.00	3.9	0.00
2007	late-	tree	1	294	0.70	4.9	0.14
2007	late-	bermuda	1	294	1.64	4.9	0.33
2007	late-	Nat/tree	1	294	1.28	4.9	0.26
2007	late-	St.A	1	294	1.62	4.9	0.33
2007	late-	native	1	294	1.30	4.9	0.27
2007	late-	St.A/tree	1	294	1.70	4.9	0.35
2007	late-	St.A	2	294	2.08	4.9	0.42
2007	late-	Nat/tree	2	294	5.51	4.9	1.12

2007	late-	native	2	294	1.58	4.9	0.32
2007	late-	tree	2	294	1.84	4.9	0.38
2007	late-	bermuda	2	294	1.39	4.9	0.28
2007	late-	St.A/tree	2	294	0.74	4.9	0.15
2007	late-	bermuda	3	294	1.04	4.9	0.21
2007	late-	tree	3	294	0.44	4.9	0.09
2007	late-	native	3	294	0.00	4.9	0.00
2007	late-	St.A/tree	3	294	2.24	4.9	0.46
2007	late-	St.A	3	294	0.57	4.9	0.12
2007	late-	Nat/tree	3	294	0.00	4.9	0.00
2007	late-	tree	1	297	1.09	4	0.27
2007	late-	bermuda	1	297	0.45	4	0.11
2007	late-	Nat/tree	1	297	0.59	4	0.15
2007	late-	St.A	1	297	1.23	4	0.31
2007	late-	native	1	297	1.46	4	0.37
2007	late-	St.A/tree	1	297	0.78	4	0.20
2007	late-	St.A	2	297	1.46	4	0.37
2007	late-	Nat/tree	2	297	2.58	4	0.65
2007	late-	native	2	297	3.51	4	0.88
2007	late-	tree	2	297	0.68	4	0.17
2007	late-	bermuda	2	297	2.71	4	0.68
2007	late-	St.A/tree	2	297	0.00	4	0.00
2007	late-	bermuda	3	297	0.10	4	0.02
2007	late-	tree	3	297	0.00	4	0.00
2007	late-	native	3	297	0.80	4	0.20
2007	late-	St.A/tree	3	297	1.59	4	0.40
2007	late-	St.A	3	297	0.84	4	0.21
2007	late-	Nat/tree	3	297	3.69	4	0.92
2007	late-	tree	1	308	2.05	2.3	0.89
2007	late-	bermuda	1	308	0.31	2.3	0.13
2007	late-	Nat/tree	1	308	0.52	2.3	0.23
2007	late-	St.A	1	308	0.89	2.3	0.39
2007	late-	native	1	308	0.00	2.3	0.00
2007	late-	St.A/tree	1	308	0.83	2.3	0.36
2007	late-	St.A	2	308	0.59	2.3	0.26
2007	late-	Nat/tree	2	308	1.94	2.3	0.84
2007	late-	native	2	308	0.10	2.3	0.04
2007	late-	tree	2	308	0.54	2.3	0.23
2007	late-	bermuda	2	308	0.43	2.3	0.18
2007	late-	St.A/tree	2	308	0.31	2.3	0.13
2007	late-	bermuda	3	308	0.44	2.3	0.19
2007	late-	tree	3	308	0.22	2.3	0.09
2007	late-	native	3	308	1.17	2.3	0.51
2007	late-	St.A/tree	3	308	0.35	2.3	0.15
2007	late-	St.A	3	308	0.95	2.3	0.41
2007	late-	Nat/tree	3	308	0.11	2.3	0.05
2007	late-	tree	1	320	0.35	2.8	0.12
2007	late-	bermuda	1	320	1.84	2.8	0.66

2007	late-	Nat/tree	1	320	0.00	2.8	0.00
2007	late-	St.A	1	320	1.62	2.8	0.58
2007	late-	native	1	320	1.32	2.8	0.47
2007	late-	St.A/tree	1	320	0.00	2.8	0.00
2007	late-	St.A	2	320	1.00	2.8	0.36
2007	late-	Nat/tree	2	320	3.39	2.8	1.21
2007	late-	native	2	320	2.54	2.8	0.91
2007	late-	tree	2	320	0.17	2.8	0.06
2007	late-	bermuda	2	320	1.89	2.8	0.67
2007	late-	St.A/tree	2	320	0.00	2.8	0.00
2007	late-	bermuda	3	320	0.18	2.8	0.06
2007	late-	tree	3	320	0.31	2.8	0.11
2007	late-	native	3	320	2.34	2.8	0.83
2007	late-	St.A/tree	3	320	1.01	2.8	0.36
2007	late-	St.A	3	320	0.00	2.8	0.00
2007	late-	Nat/tree	3	320	1.49	2.8	0.53
2008	early-	tree	1	77	0.34	3.7	0.09
2008	early-	bermuda	1	77	0.08	3.7	0.02
2008	early-	Nat/tree	1	77	0.40	3.7	0.11
2008	early-	St.A	1	77	1.37	3.7	0.37
2008	early-	native	1	77	1.13	3.7	0.31
2008	early-	St.A/tree	1	77	0.85	3.7	0.23
2008	early-	St.A	2	77	1.12	3.7	0.30
2008	early-	Nat/tree	2	77	0.45	3.7	0.12
2008	early-	native	2	77	0.13	3.7	0.04
2008	early-	tree	2	77	0.98	3.7	0.26
2008	early-	bermuda	2	77	0.00	3.7	0.00
2008	early-	St.A/tree	2	77	0.24	3.7	0.06
2008	early-	bermuda	3	77	1.71	3.7	0.46
2008	early-	tree	3	77	0.26	3.7	0.07
2008	early-	native	3	77	0.00	3.7	0.00
2008	early-	St.A/tree	3	77	0.06	3.7	0.02
2008	early-	St.A	3	77	0.06	3.7	0.02
2008	early-	Nat/tree	3	77	0.54	3.7	0.15
2008	early-	tree	1	85	0.26	3.7	0.07
2008	early-	bermuda	1	85	0.50	3.7	0.14
2008	early-	Nat/tree	1	85	1.28	3.7	0.35
2008	early-	St.A	1	85	1.68	3.7	0.45
2008	early-	native	1	85	1.08	3.7	0.29
2008	early-	St.A/tree	1	85	1.39	3.7	0.38
2008	early-	St.A	2	85	1.22	3.7	0.33
2008	early-	Nat/tree	2	85	1.37	3.7	0.37
2008	early-	native	2	85	0.62	3.7	0.17
2008	early-	tree	2	85	0.75	3.7	0.20
2008	early-	bermuda	2	85	0.66	3.7	0.18
2008	early-	St.A/tree	2	85	0.83	3.7	0.22
2008	early-	bermuda	3	85	2.09	3.7	0.57
2008	early-	tree	3	85	0.21	3.7	0.06

2008	early-	native	3	85	0.52	3.7	0.14
2008	early-	St.A/tree	3	85	1.03	3.7	0.28
2008	early-	St.A	3	85	1.46	3.7	0.40
2008	early-	Nat/tree	3	85	0.34	3.7	0.09
2008	early-	tree	1	102	0.41	3.9	0.11
2008	early-	bermuda	1	102	0.59	3.9	0.15
2008	early-	Nat/tree	1	102	0.66	3.9	0.17
2008	early-	St.A	1	102	0.36	3.9	0.09
2008	early-	native	1	102	0.35	3.9	0.09
2008	early-	St.A/tree	1	102	0.74	3.9	0.19
2008	early-	St.A	2	102	0.11	3.9	0.03
2008	early-	Nat/tree	2	102	0.24	3.9	0.06
2008	early-	native	2	102	1.25	3.9	0.32
2008	early-	tree	2	102	1.67	3.9	0.43
2008	early-	bermuda	2	102	0.99	3.9	0.25
2008	early-	St.A/tree	2	102	0.08	3.9	0.02
2008	early-	bermuda	3	102	0.63	3.9	0.16
2008	early-	tree	3	102	0.59	3.9	0.15
2008	early-	native	3	102	0.29	3.9	0.07
2008	early-	St.A/tree	3	102	0.86	3.9	0.22
2008	early-	St.A	3	102	0.90	3.9	0.23
2008	early-	Nat/tree	3	102	0.71	3.9	0.18
2008	early-	tree	1	115	0.32	4.4	0.07
2008	early-	bermuda	1	115	0.07	4.4	0.02
2008	early-	Nat/tree	1	115	0.00	4.4	0.00
2008	early-	St.A	1	115	0.08	4.4	0.02
2008	early-	native	1	115	0.51	4.4	0.11
2008	early-	St.A/tree	1	115	0.72	4.4	0.16
2008	early-	St.A	2	115	0.00	4.4	0.00
2008	early-	Nat/tree	2	115	0.05	4.4	0.01
2008	early-	native	2	115	0.79	4.4	0.18
2008	early-	tree	2	115	1.11	4.4	0.25
2008	early-	bermuda	2	115	1.74	4.4	0.40
2008	early-	St.A/tree	2	115	0.49	4.4	0.11
2008	early-	bermuda	3	115	0.17	4.4	0.04
2008	early-	tree	3	115	0.48	4.4	0.11
2008	early-	native	3	115	0.28	4.4	0.06
2008	early-	St.A/tree	3	115	0.20	4.4	0.05
2008	early-	St.A	3	115	0.43	4.4	0.10
2008	early-	Nat/tree	3	115	0.28	4.4	0.06
2008	early-	tree	1	130	1.76	4.1	0.43
2008	early-	bermuda	1	130	0.36	4.1	0.09
2008	early-	Nat/tree	1	130	0.64	4.1	0.16
2008	early-	St.A	1	130	3.36	4.1	0.82
2008	early-	native	1	130	2.04	4.1	0.50
2008	early-	St.A/tree	1	130	1.28	4.1	0.31
2008	early-	St.A	2	130	0.49	4.1	0.12
2008	early-	Nat/tree	2	130	0.43	4.1	0.10

2008	early-	native	2	130	0.00	4.1	0.00
2008	early-	tree	2	130	4.52	4.1	1.10
2008	early-	bermuda	2	130	1.29	4.1	0.31
2008	early-	St.A/tree	2	130	1.46	4.1	0.35
2008	early-	bermuda	3	130	1.77	4.1	0.43
2008	early-	tree	3	130	0.40	4.1	0.10
2008	early-	native	3	130	0.75	4.1	0.18
2008	early-	St.A/tree	3	130	0.96	4.1	0.24
2008	early-	St.A	3	130	0.70	4.1	0.17
2008	early-	Nat/tree	3	130	4.74	4.1	1.16
2008	early-	tree	1	143	0.95	5.3	0.18
2008	early-	bermuda	1	143	0.34	5.3	0.06
2008	early-	Nat/tree	1	143	0.97	5.3	0.18
2008	early-	St.A	1	143	1.70	5.3	0.32
2008	early-	native	1	143	1.59	5.3	0.30
2008	early-	St.A/tree	1	143	1.43	5.3	0.27
2008	early-	St.A	2	143	1.52	5.3	0.29
2008	early-	Nat/tree	2	143	0.54	5.3	0.10
2008	early-	native	2	143	2.26	5.3	0.43
2008	early-	tree	2	143	3.90	5.3	0.74
2008	early-	bermuda	2	143	1.08	5.3	0.20
2008	early-	St.A/tree	2	143	0.16	5.3	0.03
2008	early-	bermuda	3	143	2.47	5.3	0.47
2008	early-	tree	3	143	0.52	5.3	0.10
2008	early-	native	3	143	0.43	5.3	0.08
2008	early-	St.A/tree	3	143	1.81	5.3	0.34
2008	early-	St.A	3	143	2.37	5.3	0.45
2008	early-	Nat/tree	3	143	1.56	5.3	0.29
2008	early-	tree	1	149	0.14	4.8	0.03
2008	early-	bermuda	1	149	1.36	4.8	0.28
2008	early-	Nat/tree	1	149	1.89	4.8	0.39
2008	early-	St.A	1	149	0.76	4.8	0.16
2008	early-	native	1	149	0.80	4.8	0.17
2008	early-	St.A/tree	1	149	1.09	4.8	0.23
2008	early-	St.A	2	149	0.31	4.8	0.07
2008	early-	Nat/tree	2	149	0.66	4.8	0.14
2008	early-	native	2	149	0.48	4.8	0.10
2008	early-	tree	2	149	1.22	4.8	0.25
2008	early-	bermuda	2	149	1.33	4.8	0.28
2008	early-	St.A/tree	2	149	0.12	4.8	0.02
2008	early-	bermuda	3	149	0.79	4.8	0.16
2008	early-	tree	3	149	0.71	4.8	0.15
2008	early-	native	3	149	0.09	4.8	0.02
2008	early-	St.A/tree	3	149	1.56	4.8	0.33
2008	early-	St.A	3	149	0.09	4.8	0.02
2008	early-	Nat/tree	3	149	0.34	4.8	0.07
2008	mid-	tree	1	157	0.12	6.7	0.02
2008	mid-	bermuda	1	157	2.93	6.7	0.44

2008	mid-	Nat/tree	1	157	3.01	6.7	0.45
2008	mid-	St.A	1	157	2.75	6.7	0.41
2008	mid-	native	1	157	2.88	6.7	0.43
2008	mid-	St.A/tree	1	157	2.35	6.7	0.35
2008	mid-	St.A	2	157	1.95	6.7	0.29
2008	mid-	Nat/tree	2	157	0.45	6.7	0.07
2008	mid-	native	2	157	1.42	6.7	0.21
2008	mid-	tree	2	157	0.80	6.7	0.12
2008	mid-	bermuda	2	157	2.64	6.7	0.39
2008	mid-	St.A/tree	2	157	1.90	6.7	0.28
2008	mid-	bermuda	3	157	1.43	6.7	0.21
2008	mid-	tree	3	157	0.85	6.7	0.13
2008	mid-	native	3	157	0.00	6.7	0.00
2008	mid-	St.A/tree	3	157	2.68	6.7	0.40
2008	mid-	St.A	3	157	2.60	6.7	0.39
2008	mid-	Nat/tree	3	157	0.22	6.7	0.03
2008	mid-	tree	1	164	0.96	6.7	0.14
2008	mid-	bermuda	1	164	1.42	6.7	0.21
2008	mid-	Nat/tree	1	164	2.14	6.7	0.32
2008	mid-	St.A	1	164	1.81	6.7	0.27
2008	mid-	native	1	164	1.08	6.7	0.16
2008	mid-	St.A/tree	1	164	2.08	6.7	0.31
2008	mid-	St.A	2	164	1.81	6.7	0.27
2008	mid-	Nat/tree	2	164	0.69	6.7	0.10
2008	mid-	native	2	164	0.49	6.7	0.07
2008	mid-	tree	2	164	1.13	6.7	0.17
2008	mid-	bermuda	2	164	3.94	6.7	0.59
2008	mid-	St.A/tree	2	164	2.12	6.7	0.32
2008	mid-	bermuda	3	164	0.80	6.7	0.12
2008	mid-	tree	3	164	0.58	6.7	0.09
2008	mid-	native	3	164	0.52	6.7	0.08
2008	mid-	St.A/tree	3	164	2.58	6.7	0.39
2008	mid-	St.A	3	164	2.33	6.7	0.35
2008	mid-	Nat/tree	3	164	0.23	6.7	0.03
2008	mid-	tree	1	171	0.76	6.1	0.12
2008	mid-	bermuda	1	171	1.43	6.1	0.23
2008	mid-	Nat/tree	1	171	1.08	6.1	0.18
2008	mid-	St.A	1	171	1.15	6.1	0.19
2008	mid-	native	1	171	0.74	6.1	0.12
2008	mid-	St.A/tree	1	171	1.09	6.1	0.18
2008	mid-	St.A	2	171	1.02	6.1	0.17
2008	mid-	Nat/tree	2	171	0.48	6.1	0.08
2008	mid-	native	2	171	0.50	6.1	0.08
2008	mid-	tree	2	171	2.76	6.1	0.45
2008	mid-	bermuda	2	171	3.44	6.1	0.56
2008	mid-	St.A/tree	2	171	1.67	6.1	0.27
2008	mid-	bermuda	3	171	1.37	6.1	0.22
2008	mid-	tree	3	171	0.88	6.1	0.14

2008	mid-	native	3	171	0.48	6.1	0.08
2008	mid-	St.A/tree	3	171	2.33	6.1	0.38
2008	mid-	St.A	3	171	1.09	6.1	0.18
2008	mid-	Nat/tree	3	171	0.17	6.1	0.03
2008	mid-	tree	1	178	1.16	6.6	0.18
2008	mid-	bermuda	1	178	0.46	6.6	0.07
2008	mid-	Nat/tree	1	178	1.34	6.6	0.20
2008	mid-	St.A	1	178	1.49	6.6	0.23
2008	mid-	native	1	178	1.85	6.6	0.28
2008	mid-	St.A/tree	1	178	0.84	6.6	0.13
2008	mid-	St.A	2	178	1.49	6.6	0.23
2008	mid-	Nat/tree	2	178	0.56	6.6	0.08
2008	mid-	native	2	178	0.00	6.6	0.00
2008	mid-	tree	2	178	2.21	6.6	0.33
2008	mid-	bermuda	2	178	2.23	6.6	0.34
2008	mid-	St.A/tree	2	178	0.74	6.6	0.11
2008	mid-	bermuda	3	178	1.27	6.6	0.19
2008	mid-	tree	3	178	0.62	6.6	0.09
2008	mid-	native	3	178	0.32	6.6	0.05
2008	mid-	St.A/tree	3	178	1.79	6.6	0.27
2008	mid-	St.A	3	178	1.22	6.6	0.19
2008	mid-	Nat/tree	3	178	0.71	6.6	0.11
2008	mid-	tree	1	199	0.45	5.9	0.08
2008	mid-	bermuda	1	199	1.44	5.9	0.24
2008	mid-	Nat/tree	1	199	1.29	5.9	0.22
2008	mid-	St.A	1	199	0.73	5.9	0.12
2008	mid-	native	1	199	1.97	5.9	0.33
2008	mid-	St.A/tree	1	199	2.17	5.9	0.37
2008	mid-	St.A	2	199	0.74	5.9	0.13
2008	mid-	Nat/tree	2	199	1.64	5.9	0.28
2008	mid-	native	2	199	0.04	5.9	0.01
2008	mid-	tree	2	199	2.44	5.9	0.41
2008	mid-	bermuda	2	199	2.26	5.9	0.38
2008	mid-	St.A/tree	2	199	0.00	5.9	0.00
2008	mid-	bermuda	3	199	0.49	5.9	0.08
2008	mid-	tree	3	199	0.87	5.9	0.15
2008	mid-	native	3	199	0.00	5.9	0.00
2008	mid-	St.A/tree	3	199	0.78	5.9	0.13
2008	mid-	St.A	3	199	0.49	5.9	0.08
2008	mid-	Nat/tree	3	199	0.43	5.9	0.07
2008	mid-	tree	1	204	0.84	7.3	0.12
2008	mid-	bermuda	1	204	0.37	7.3	0.05
2008	mid-	Nat/tree	1	204	0.53	7.3	0.07
2008	mid-	St.A	1	204	1.65	7.3	0.23
2008	mid-	native	1	204	0.92	7.3	0.13
2008	mid-	St.A/tree	1	204	3.91	7.3	0.54
2008	mid-	St.A	2	204	2.30	7.3	0.32
2008	mid-	Nat/tree	2	204	0.40	7.3	0.05

2008	mid-	native	2	204	4.01	7.3	0.55
2008	mid-	tree	2	204	2.64	7.3	0.36
2008	mid-	bermuda	2	204	2.99	7.3	0.41
2008	mid-	St.A/tree	2	204	1.46	7.3	0.20
2008	mid-	bermuda	3	204	1.57	7.3	0.21
2008	mid-	tree	3	204	1.42	7.3	0.19
2008	mid-	native	3	204	0.65	7.3	0.09
2008	mid-	St.A/tree	3	204	1.77	7.3	0.24
2008	mid-	St.A	3	204	0.62	7.3	0.09
2008	mid-	Nat/tree	3	204	0.54	7.3	0.07
2008	mid-	tree	1	213	0.28	7.3	0.04
2008	mid-	bermuda	1	213	1.41	7.3	0.19
2008	mid-	Nat/tree	1	213	1.98	7.3	0.27
2008	mid-	St.A	1	213	0.54	7.3	0.07
2008	mid-	native	1	213	0.99	7.3	0.14
2008	mid-	St.A/tree	1	213	1.37	7.3	0.19
2008	mid-	St.A	2	213	1.15	7.3	0.16
2008	mid-	Nat/tree	2	213	0.25	7.3	0.03
2008	mid-	native	2	213	0.44	7.3	0.06
2008	mid-	tree	2	213	1.93	7.3	0.26
2008	mid-	bermuda	2	213	2.00	7.3	0.27
2008	mid-	St.A/tree	2	213	0.67	7.3	0.09
2008	mid-	bermuda	3	213	0.28	7.3	0.04
2008	mid-	tree	3	213	0.90	7.3	0.12
2008	mid-	native	3	213	0.20	7.3	0.03
2008	mid-	St.A/tree	3	213	1.01	7.3	0.14
2008	mid-	St.A	3	213	1.90	7.3	0.26
2008	mid-	Nat/tree	3	213	0.75	7.3	0.10
2008	mid-	tree	1	223	1.02	6.2	0.16
2008	mid-	bermuda	1	223	0.47	6.2	0.08
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2008	mid-	St.A	1	223	0.84	6.2	0.13
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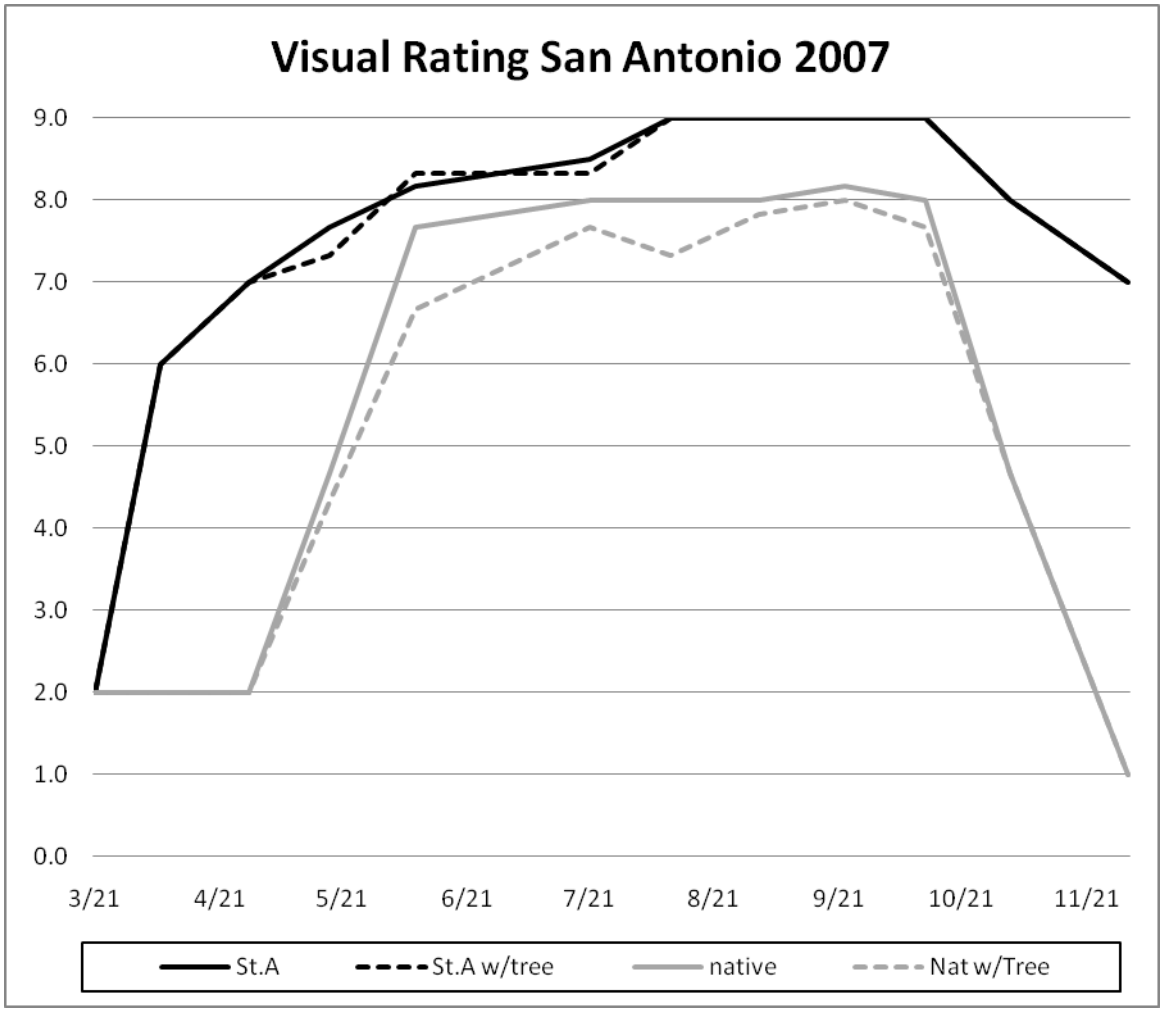
2008	mid-	tree	2	223	3.87	6.2	0.62
2008	mid-	bermuda	2	223	0.63	6.2	0.10
2008	mid-	St.A/tree	2	223	0.00	6.2	0.00
2008	mid-	bermuda	3	223	1.05	6.2	0.17
2008	mid-	tree	3	223	0.39	6.2	0.06
2008	mid-	native	3	223	0.00	6.2	0.00
2008	mid-	St.A/tree	3	223	0.59	6.2	0.10
2008	mid-	St.A	3	223	1.91	6.2	0.31
2008	mid-	Nat/tree	3	223	0.00	6.2	0.00
2008	late-	tree	1	270	0.13	4	0.03
2008	late-	bermuda	1	270	0.04	4	0.01

2008	late-	Nat/tree	1	270	0.77	4	0.19
2008	late-	St.A	1	270	0.43	4	0.11
2008	late-	native	1	270	1.67	4	0.42
2008	late-	St.A/tree	1	270	0.32	4	0.08
2008	late-	St.A	2	270	0.34	4	0.09
2008	late-	Nat/tree	2	270	0.29	4	0.07
2008	late-	native	2	270	0.83	4	0.21
2008	late-	tree	2	270	0.22	4	0.05
2008	late-	bermuda	2	270	1.29	4	0.32
2008	late-	St.A/tree	2	270	1.70	4	0.43
2008	late-	bermuda	3	270	0.12	4	0.03
2008	late-	tree	3	270	0.81	4	0.20
2008	late-	native	3	270	1.45	4	0.36
2008	late-	St.A/tree	3	270	0.40	4	0.10
2008	late-	St.A	3	270	0.51	4	0.13
2008	late-	Nat/tree	3	270	0.69	4	0.17
2008	late-	tree	1	277	0.26	5.1	0.05
2008	late-	bermuda	1	277	0.27	5.1	0.05
2008	late-	Nat/tree	1	277	2.00	5.1	0.39
2008	late-	St.A	1	277	0.24	5.1	0.05
2008	late-	native	1	277	0.56	5.1	0.11
2008	late-	St.A/tree	1	277	1.16	5.1	0.23
2008	late-	St.A	2	277	0.23	5.1	0.05
2008	late-	Nat/tree	2	277	0.35	5.1	0.07
2008	late-	native	2	277	0.62	5.1	0.12
2008	late-	tree	2	277	0.19	5.1	0.04
2008	late-	bermuda	2	277	1.31	5.1	0.26
2008	late-	St.A/tree	2	277	0.22	5.1	0.04
2008	late-	bermuda	3	277	0.05	5.1	0.01
2008	late-	tree	3	277	0.92	5.1	0.18
2008	late-	native	3	277	0.08	5.1	0.01
2008	late-	St.A/tree	3	277	0.98	5.1	0.19
2008	late-	St.A	3	277	0.93	5.1	0.18
2008	late-	Nat/tree	3	277	1.61	5.1	0.31
2008	late-	tree	1	288	0.17	3	0.06
2008	late-	bermuda	1	288	0.24	3	0.08
2008	late-	Nat/tree	1	288	0.74	3	0.25
2008	late-	St.A	1	288	0.16	3	0.05
2008	late-	native	1	288	0.52	3	0.17
2008	late-	St.A/tree	1	288	0.00	3	0.00
2008	late-	St.A	2	288	0.45	3	0.15
2008	late-	Nat/tree	2	288	0.42	3	0.14
2008	late-	native	2	288	0.89	3	0.30
2008	late-	tree	2	288	0.05	3	0.02
2008	late-	bermuda	2	288	0.74	3	0.25
2008	late-	St.A/tree	2	288	0.71	3	0.24
2008	late-	bermuda	3	288	0.00	3	0.00
2008	late-	tree	3	288	0.19	3	0.06

2008	late-	native	3	288	0.00	3	0.00
2008	late-	St.A/tree	3	288	0.50	3	0.17
2008	late-	St.A	3	288	0.53	3	0.18
2008	late-	Nat/tree	3	288	0.00	3	0.00
2008	late-	tree	1	297	1.45	3.30	0.44
2008	late-	bermuda	1	297	0.57	3.30	0.17
2008	late-	Nat/tree	1	297	0.30	3.30	0.09
2008	late-	St.A	1	297	0.59	3.30	0.18
2008	late-	native	1	297	1.06	3.30	0.32
2008	late-	St.A/tree	1	297	1.05	3.30	0.32
2008	late-	St.A	2	297	0.91	3.30	0.28
2008	late-	Nat/tree	2	297	0.12	3.30	0.04
2008	late-	native	2	297	0.65	3.30	0.20
2008	late-	tree	2	297	0.34	3.30	0.10
2008	late-	bermuda	2	297	1.57	3.30	0.48
2008	late-	St.A/tree	2	297	1.01	3.30	0.31
2008	late-	bermuda	3	297	0.53	3.30	0.16
2008	late-	tree	3	297	0.86	3.30	0.26
2008	late-	native	3	297	0.00	3.30	0.00
2008	late-	St.A/tree	3	297	0.70	3.30	0.21
2008	late-	St.A	3	297	1.27	3.30	0.38
2008	late-	Nat/tree	3	297	0.07	3.30	0.02

APPENDIX E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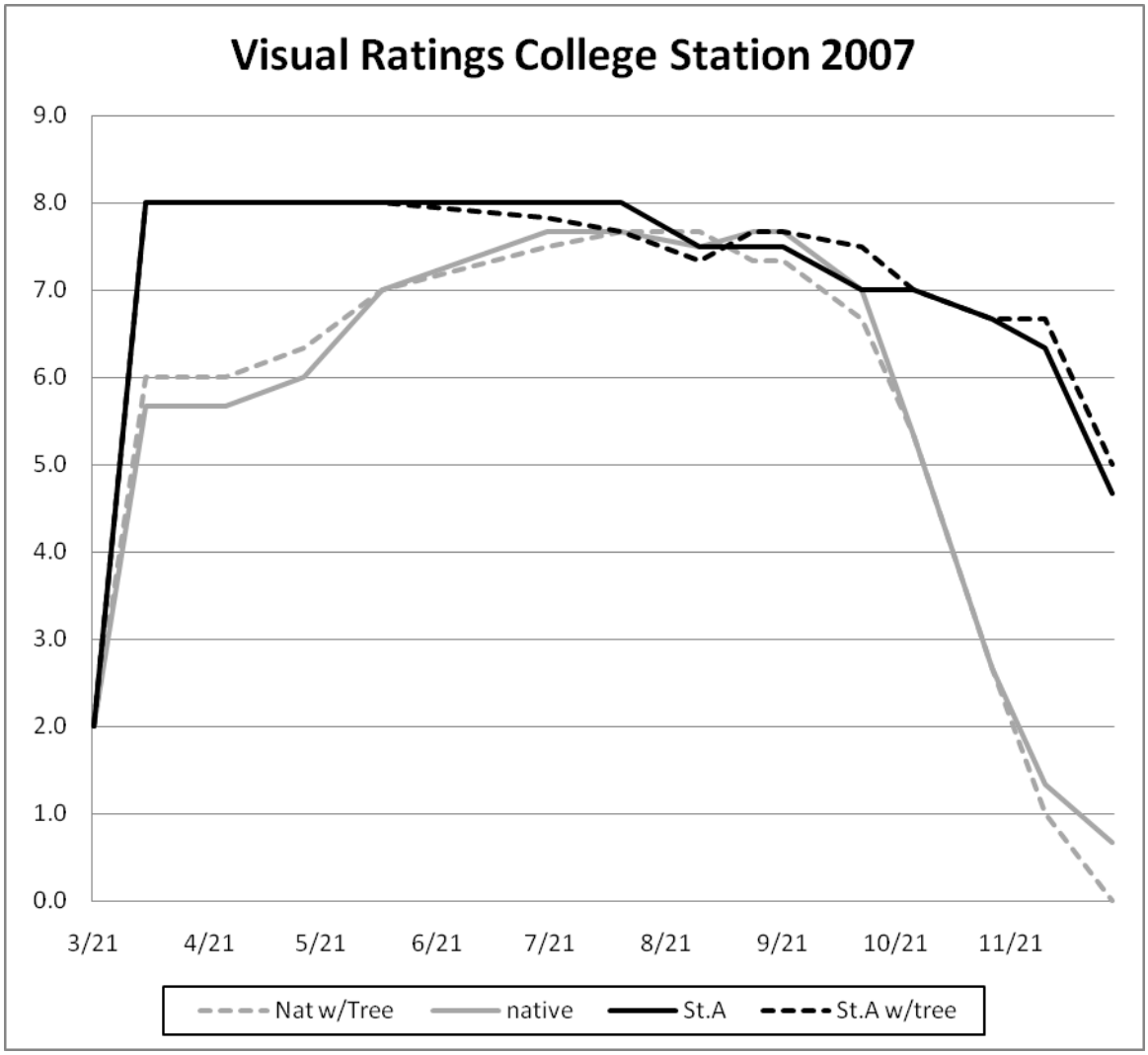
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
3/21
4/21
5/21
6/21
7/21
8/21
9/21
10/21
11/21
St.A
St.A w/tree
native
Nat w/Tree


Visual Ratings College Station 2007
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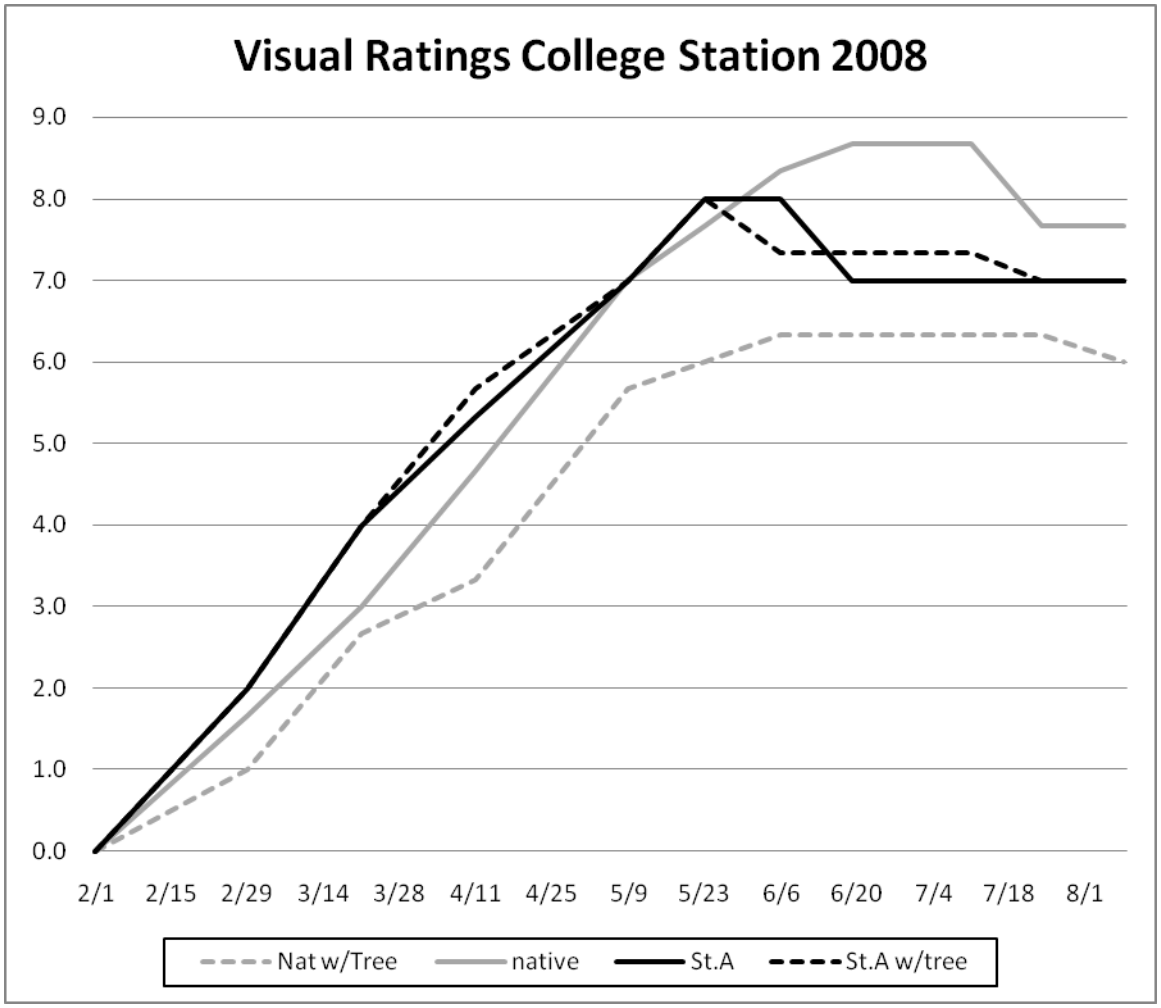
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
3/21
4/21
5/21
6/21
7/21
8/21
9/21
10/21
11/21
Nat w/Tree
native
St.A
St.A w/tree


Visual Ratings College Station 2008
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2/1
2/15
2/29
3/14
3/28
4/11
4/25
5/9
5/23
6/6
6/20
7/4
7/18
8/1
Nat w/Tree
native
St.A
St.A w/tree

VITA

Timothy Richard Pannkuk received his Bachelor of Science degree in horticulture from Texas A&M University in May 1990. He entered the lawncare/ landcare industry and remained until entering graduate school at Texas A&M University in Jan 1993. A Master of Science degree in horticulture was awarded in 1995. He spent another six and one-half years in industry before returning to academia. Mr. Pannkuk has worked full-time as a lecturer since the spring of 2002. His research interests include landscape water conservation and education. He plans to publish journal articles and popular articles on these topics.

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